SCHEDULE ADHERENCE IN A NAVAL SHIPYARD--- A CASE STUDY

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NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

SCHEDULE ADHERENCE IN A NAVAL SHIPYARD---

A CASE STUDY

by

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September 1976

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In this research, the author documents the process of production management employed in a naval shipyard in seeking adherence to schedules during the non-nuclear portion of the overhaul of nuclear submarines. In addition to recording the process details for those who may learn from them in the future, the author also demonstrates some of the problems confronting managers in all naval shipyards.

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The author first profiles the history, mission, and organization of the activity chosen for the research, Mare Island Naval Shipyard, then develops the process constraints of estimated cost, schedule, personnel resources, and authorized work packages for an individual ship. The discussion then shifts to a detailed description of the management aids used to monitor and assess overhaul progress and of the techniques employed, using these aids, to seek schedule adherence on several ships simultaneously. The research concludes with a summary of the total process and suggestions for further research.

Schedule Adherence in a Naval Shipyard---

A Case Study

by

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In this research, the author documents the process of production management employed in a naval shipyard in seeking adherence to schedules during the non-nuclear portion of the overhaul of nuclear submarines. In addition to recording the process details for those who may learn from them in the future, the author also demonstrates some of the problems confronting managers in all naval shipyards. The author first profiles the history, mission, and organization of the activity chosen for the research, Mare Island Naval Shipyard, then develops the process constraints of estimated cost, schedule, personnel resources, and authorized work packages for an individual ship. The discussion then shifts to a detailed description of the management aids used to monitor and assess overhaul progress and of the techniques employed, using these aids, to seek schedule adherence on several ships simultaneously. The research concludes with a summary of the total process and suggestions for further research.

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I. INTRODUCTION

A. PURPOSE

The purpose of this research is to document and explain the management techniques employed by senior management in a Naval shipyard in striving to achieve schedule adherence during nuclear submarine overhauls. Compounding this problem are explicit constraints in the form of personnel resources and implicit constraints in the form of cost factors, all of which dictate that tradeoffs constantly be made. These constraints result from an overhaul schedule imposed by higher authority as shall be seen. The process analyzed was thus one of production management in an environment of limited physical resources.

B. SCOPE

The research was intentionally limited in scope to insure sufficient depth of investigation. Only one overhauling activity, Mare Island Naval Shipyard, was consulted, and only the non-nuclear portion of that activity's management process was specifically addressed. The author fully recognized that the techniques employed by other shipyards may be different from those described herein and that even within the shipyard investigated there are significant process differences between the non-nuclear and nuclear overhaul management phases. Having thus acknowledged that this thesis presents only a portion

of the total picture of present day overhaul management techniques, the author nevertheless maintains that the process description presented is accurate and may be used to gain insight into the typical problems facing the managers of all shipyards.

C. PERSPECTIVE

As will become apparent, the author found that there were many perspectives from which to address the research. It was apparent early in the research, however, that the day-to-day common denominator for non-nuclear production management matters at Mare Island was the Repair Officer. The research thus addresses the process mainly from the Repair Officer's perspective by describing the inputs and techniques used by that officer to effect coordinated production management among several overhauling ships.

D. RESEARCH TECHNIQUE

Although some background reading was done (to be discussed later) the research effort consisted largely of personal interviews by the author with key shipyard officials over a period of 11 weeks. The author obtained complete cooperation in the research from all officials contacted. In an effort to insure that the facts derived from these interviews were stated correctly, the Repair Officer and the Shipyard Commander were afforded an opportunity to provide comments on the accuracy of the research.

E. FRAMEWORK OF THE ANALYSIS

Chapter II describes the overall organization of Mare Island Naval Shipyard and presents that activity's strategic profile. Chapter III provides further background by describing a typical sequence of events in the overhaul of a nuclear submarine at Mare Island. Chapter IV discusses the detailed development of the constraints within which the Repair Officer must work---schedule, estimated cost, personnel resources, and work package---and describes the interrelationships among these constraints. Chapter V discusses the details of the management tools used by the Repair Officer in his role as production coordinator and "whip". Chapter VI discusses his use of these tools to manage the production effort for all overhauling ships simultaneously and describes the tradeoff problems involved. Chapter VII provides a summary of the overall process and Chapter VIII suggests topics for further research.

II. DESCRIPTION, ORGANIZATION, AND STRATEGIC PROFILE OF MARE ISLAND NAVAL SHIPYARD

A. MARE ISLAND AS A MEMBER OF THE NAVAL SHIPYARD COMPLEX

Mare Island Naval Shipyard is one of eight members of the Naval Shipyard Complex, the other member yards being located in Portsmouth, N.H., Philadelphia, Norfolk, Charleston, Bremerton, Washington (Puget Sound), Long Beach, and Pearl Harbor. The official mission of this complex is:

> "To provide logistic support for assigned ships and service craft; to perform authorized work in connection with construction, conversion, overhaul, repair, alteration, drydocking, and outfitting of ships and craft, as assigned; to perform manufacturing, research, and test work, as assigned; and to provide services and material to other activities and units, as directed by competent authority." [1]

Although each naval shipyard can perform a variety of services in consonance with this mission, Commander, Naval Sea Systems Command (hereafter, NAVSEA) has designated special uses for each of these yards. For Mare Island Naval Shipyard, the specialty mission involves the construction, conversion and overhaul of all types of submarines and the overhaul of surface ships, including nuclear, except aircraft carriers [1]. Since reference 1 was published, the ship construction mission was deleted for all naval shipyards but portions of this capability still remain at Mare Island. Reactivation of Mare Island's submarine construction capability would require considerable retooling and the

acquisition and training of specialized trades to obtain the balance of skills that are different from the present needs during overhauls. To adequately re-establish a construction capability from the personnel standpoint would require at least two years.

B. LOCATION

Mare Island Naval Shipyard is located in Vallejo, California at the northeastern corner of San Pablo Bay at the mouth of the Napa River. From an initial land purchase by the Navy of only 956 acres in 1853, Mare Island has grown through land reclamation and grants to a present size of over 2600 acres of hard land and almost 1900 acres of tidelands [2].

C. SIZE AND COMPOSITION OF WORK FORCE

Although the size and composition by trade of the workforce in naval shipyards varies with the requirements of the work (see Chapter IV for further details), Mare Island, with a total shipyard employment of over 9800 of which approximately 6470 work in the production area, ranks third in terms of work force behind Puget Sound and Norfolk Naval Shipyards [3,4]. Of this total production department workforce, approximately 1750 are available as indirect labor and 3960 as direct labor on any given day (the remaining 760 workers are projected daily absentees) [3] The direct labor force includes all non-salaried workers less supervisors whose time is charged against specific authorized work items on ships undergoing repairs. Indirect labor thus includes salaried

and supervisory personnel whose work is not directly traceable to specific authorized work items. In addition to this civilian complement, Mare Island is assigned about 50 military officers and senior petty officers in varying capacities from Shipyard Commander to ship superintendent.

A serious workforce problem confronting Mare Island management is an average shortage, projected through 1976 based upon existing schedules, of over 650 direct labor mandays per day when the available direct labor is compared with the estimated direct labor requirements [3]. The impact of this shortage is to require more overtime and subcontracting that might otherwise be necessary. This shortage, together with overtime use restrictions, reduces management's flexibility in using overtime on important work. This point will be discussed more fully in Chapter VI.

Another workforce problem for Mare Island is the decline in the ratio of skilled to unskilled workers in recent years (from a high of 6.5:1 in May 1973 to 2.2:1 by December 1975). This decline was caused by a Reduction in Force (RIF) of about 4000 workers in 1973 coupled with the retirement of many skilled World War II workers and the subsequent need, as workload increased, to fill many of these previously skilled positions with unskilled labor. Contributing to this problem was a changing workforce profile as the shipyard new construction mission was deleted. The impact of this reduced skill level factor on the direct labor mandays required to complete the overhaul of one recent submarine as opposed to another of the

same class completed previously when this factor was not as prevalent was estimated to be over 18,000 mandays. This was over 25 percent of the total manday increase experienced in the more recent ship.

D. ORGANIZATION

Because the orientation of this research was on non-nuclear production management, only those portions of the shipyard organization pertaining to that subject will be discussed.

Figure 1 shows the organization of the Production Department at Mare Island as it pertains to non-nuclear production management. The Production Officer (Code 300) has direct access to the Shipyard Commander for matters pertaining to production. The majority of the day-to-day decisions in the Production Department regarding production emphasis and resource use, however, are made by the Repair Officer (Code 330) consistent with Shipyard Commander and Production Officer guidance on project priorities. Reporting directly to the Repair Officer are the Assistant Repair Officers (where assigned) and, by convention, the ship superintendents for each vessel. (Mare Island does not use the Project Officer organizational concept wherein a Project Officer is assigned to each overhauling vessel.) The ship superintendents function as the Repair Officer's representatives for each vessel in overhaul, serving to plan, coordinate, and expedite the accomplishment of scheduled repairs. Also reporting to the Repair Officer are the heads of the Shipwork Control Center

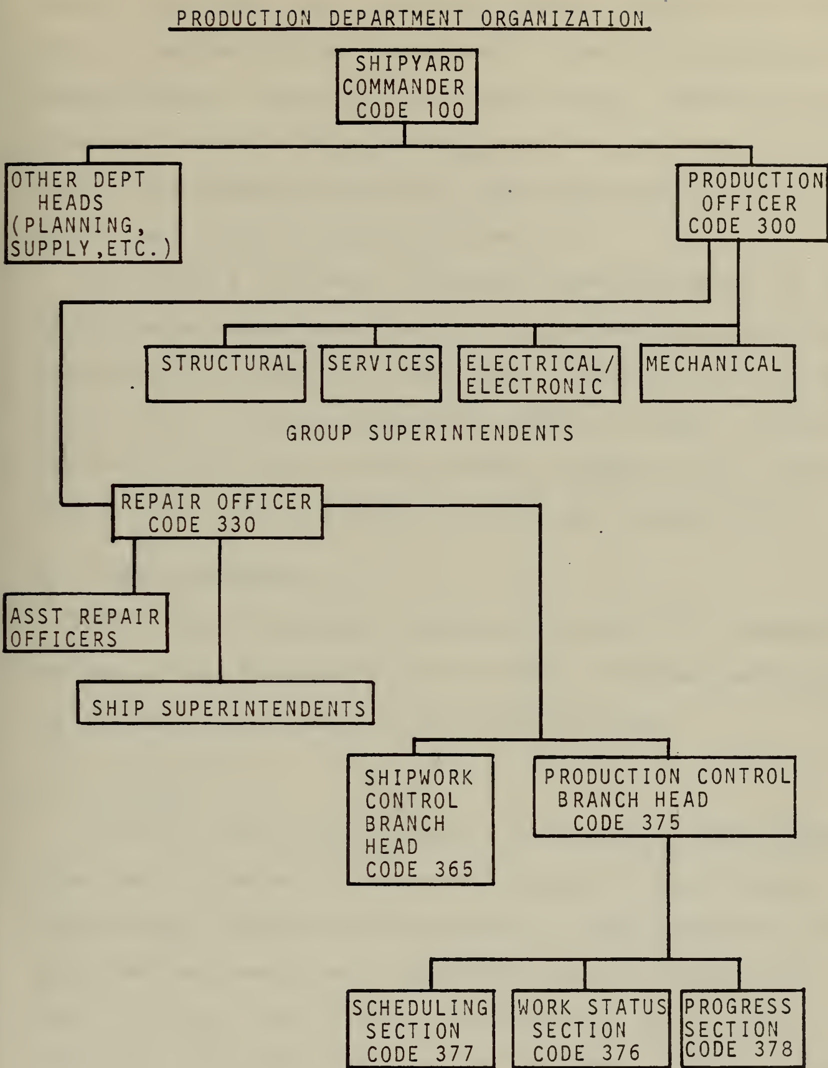

FIGURE 1. Production Department Organization Chart (Partial)

Branch (Code 365), the Production Control Branch (Code 375), and the Docking Officer (Code 340). Within the Production Control Branch, three sections (Work Status, Scheduling, and Progress) maintain daily control over the administration of the various documents used for those functions (to be discussed more fully in Chapters IV and V).

As figure 1 indicates, the group superintendents for each of the major trade areas (structural, mechanical, electrical/electronics, and service) also report directly to the Production Officer. Within these major trade groupings are the individual shops (pipe, inside machine, riggers, etc.), each with a shop head who reports to the group superintendent.

E. IMMEDIATE SENIOR

The Shipyard Commander reports to NAVSEA (07) (Industrial and Facilities Management Directorate) on matters pertaining to the operation of Mare Island Naval Shipyard.

F. CUSTOMER

With its traditional submarine orientation, Mare Island's "customer" is normally Commander Submarine Force, Pacific (COMSUBPAC). Submarines overhauling in Mare Island are administratively assigned to COMSUBPAC for the duration of their overhaul, even if they will return to the Atlantic Fleet upon its completion. As the customer, COMSUBPAC functions as Type Commander to insure that the overhaul funds available to Commander-in-Chief, Pacific Fleet (CINCPACFLT) (who pays for the overhaul) are properly spent [5]. For

surface ship overhauls for ships under his control, Commander Surface Force, Pacific (COMSURFPAC) assumes the customer function.

G. SHIP LOADING AND WORK ASSIGNMENT

As a naval shipyard, Mare Island does not "bid" for overhaul contracts in the same way that a private shipyard does. In fact, Mare Island workload is not a matter of choice for the shipyard but rather, is assigned by NAVSEA and the Chief of Naval Operations through the aid of a computerized Long Range Planning System (LRPS) which uses as inputs the existing CNO three year construction, conversion, and overhaul schedules and the known scope of work required on a given ship. By comparing these inputs against yard capabilities (in terms of manpower and docking space), yard specialties (submarines for Mare Island), existing homeport policies, shipwork priorities, and the desired split between naval and private shipyards, the LRPS produces as an output a 10-year distribution of workload by public and naval shipyard [6]. The LRPS output is subjected to the review of both NAVSEA and CNO prior to approval and is issued in the form of an OPNAV Notice (4710 series) which assigns ship overhauls to specific shipyards for specific periods for the next 24 months. Mare Island has a formal input to the workload assignment process in the form of a monthly Planned Workload and Employment Report (NAVSHIPS Form 12280/4) which shows actual and projected workloads for the current month and the next nine months. In addition, informal means (telephone, etc.) may

be used before the fact to convey the desirability or undesirability of a particular ship assignment to the ultimate decision-makers.

The approved LRPS output as discussed above has resulted in an approximate average submarine overhaul shipload at Mare Island as follows:

Calendar Year	Rounded Average (nuclear (SSN/SSBN) and non-nuclear (SS))
1974	6
1975	7
1976	7
1977	6 (projected)
1978	5 (projected)

In interpreting this loading data, the reader should recognize that, in addition to vessels in overhaul, Mare Island also simultaneously conducts assigned restricted availabilities on submarines, normally of about 8 weeks duration, and starting in 1978 (projected), will be assigned at least one surface ship overhaul.[1] Further, because the nuclear submarines involved are typically older (SSN 585 or 594 Class, SSBN 598 or 608 Class) the productive workload on these ships is greater than would be necessary on a new ship.

Although the projected LRPS ship assignments are available for use by the shipyard considerably in advance, e.g.,

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[1]As used here, restricted availability refers to a period of time during which a ship is made available to the shipyard for the accomplishment of specific items of work. During this time period, the ship is rendered incapable of performing its assigned mission and tasks due to the nature of the repair work.

1977 and 1978 projections above, Mare Island does not use these shipload projections as personnel procurement/release authority since they are subject to change. Augmentation or reductions in the labor force are made only upon issuance of an OPNAV NOTE 4710 confirming the ship assignments and in compliance with existing labor contracts.

H. THE PRODUCTION MANAGEMENT GOAL

Mare Island defines its goal insofar as production management and schedule adherence are concerned in the following manner [7]:

> "..... they (shipyard managers) shall manage their manpower to accomplish scheduled work on time and at minimum cost."[2]

The purpose of this research, as stated earlier, is to explain how Mare Island approaches this problem in day-to-day management.

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[2]Implicit in this statement is the understanding that coincident with efforts to achieve schedule adherence there are to be simultaneous efforts to minimize the cost of achieving that schedule.

III. A TYPICAL OVERHAUL SEQUENCE

A. PURPOSE

This chapter provides the reader with additional background by presenting a typical overhaul sequence and defining the Key Event concept.

B. KEY EVENTS

Key events play an extremely important role in the management of overhauls by providing management with discrete, well-defined checkpoints at which the status of work may be determined and evaluated. Key events are simply points in the overall sequence of work on a system or systems which the shipyard or higher authority has determined are important milestones relative to the progressing of work completion. All authorized shipyard work is issued by a job order written by a planner. In addition to providing a means of charging the customer via the job order number, this document describes in detail the work to be done and relates the separate work elements to key events. Prior to each key event, an administrative review may be conducted to determine that all required work is completed (Chapter V discusses this aspect of control in detail).

Although Mare Island has defined over 800 such events for purposes of work status determination, the author has selected nine of these which represent major status changes in the ship or ship systems for purposes of describing the overhaul

sequence. These same key events typically define the "critical path" (or longest path to completion) as well. They are ship arrival, drydocking, primary (reactor) plant fill, undocking, engine room steaming, reactor plant hot operations, reactor plant criticality, sea trials, and ship completion.

Figure 2 depicts a recent SSBN overhaul initial schedule in terms of these key events. The number associated with each event is the days after ship arrival at which the event is expected to start. While this 12 1/2 month schedule supports an SSBN overhaul of 15 month allowed duration (the reason for this apparent discrepancy will be discussed in Chapter IV), different ships with different allowed overhaul lengths would still follow the same approximate sequencing. Only the length of the sequence would change in those cases.

C. DESCRIPTION OF OVERHAUL PHASES

The portion of the overhaul from ship arrival and drydocking until primary plant fill is the period of peak projected overhaul manning. During this time period, hull access cuts are made, all major ripout and unshipping is completed, the hull and ballast tank areas are repaired and preserved, and work on those reactor plant and non-reactor plant systems necessary to support the reactor plant fill evolution is completed to the necessary degree. During this period ractor plant refueling is conducted and most of the work necessary to support undocking is completed. For this and other major key events, the shipyard prepares prerequisite listings incorporating the requirements of higher

TYPICAL OVERHAUL SEQUENCE

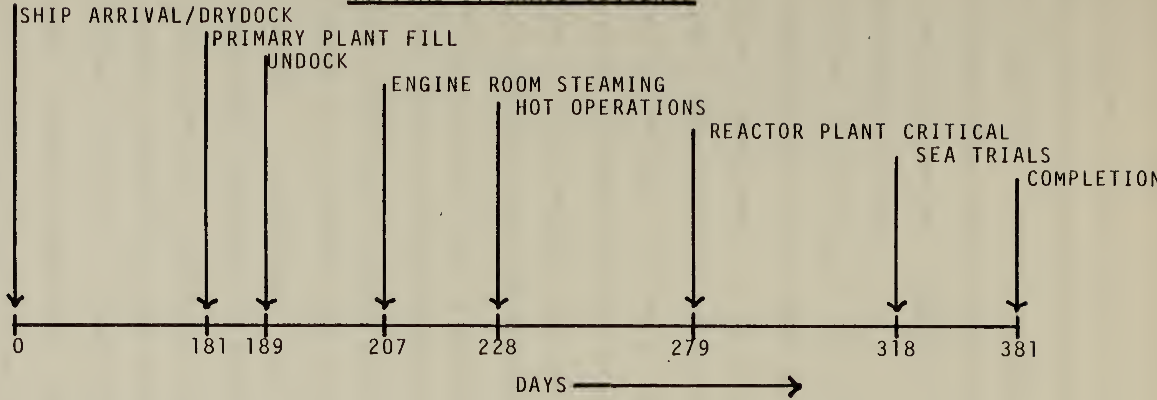


FIGURE 2. Typical Overhaul Sequence of Events

authority [8,9] and any other special requirements which may exist because of conditions at the time. Final review and signing of these prerequisite lists by the shipyard and ship's force constitutes concurrence that the required system status as defined by the prerequisite list is achieved and that the key event may proceed. Chapter V further addresses the use of prerequisite lists.

Between the filling of the reactor plant and undocking, the remainder of the work necessary for safe waterborne operation is completed. This includes, where not already completed, reinstallation of major components too large to fit through hatches, closure of major hull access cuts, and restoration of double barrier protection between open internal portions of sea-connected systems and the sea. Incorporated in the preparation for the undocking event are also provisions for emergency dewatering of compartment bilges, ballast tank blow, and interior communications for damage control purposes.

From undocking to engine room steaming, considerable testing begins in electronics and fire control components reinstalled prior to undocking. In the propulsion area, emphasis is placed upon preparing the steam, condensate and associated cooling systems for the shore steaming evolution. Typically, the systems required for this event (or portions thereof) are flushed, restored, and subjected to a strength and tightness test to verify integrity. Operational tests are also conducted following tightness testing. During this period,

cold (less than 200°F) operations of this type in the reactor plant area are also conducted. Once the prerequisite list for engine room steaming is completed, shore steam is used to test the steam-driven engine room components.

From the start of engine room steaming until reactor plant hot operations commence, emphasis shifts again to providing the necessary non-nuclear system status to support the latter event. In practice, most of this work is already completed and the two events can usually proceed almost without interruption except for the necessary flushing which must follow the use of shore steam. In fact, the shipyard generally schedules these two events to occur at the same time so that the option exists to proceed with whichever is most ready. Once again, after engine room steaming completes, a prerequisite list is signed and reactor plant hot operations (at or near normal temperature) commences.

Reactor plant criticality, the next major key event, is very demanding in terms of requirements placed upon non-nuclear systems. This event is preceded by a thorough inspection of the entire engineering spaces by representatives of the shipyard, ship's force, NAVSEA (08), and the reactor plant contractor to determine readiness for this event. Except for minor touchup painting, stowage-for-sea, removal of special test instrumentation, and other non-operational deficiencies, Mare Island seeks to have the engineering spaces essentially ready for sea at the time of reactor plant criticality. In fact, the ship's force signature on the

prerequisite list for criticality normally constitutes final acceptance of the systems involved except for emergent deficiencies during trials.

Following criticality, emphasis traditionally shifts to completing non-engineering work in the weapons, navigation, communications, and tactical sensor areas. During this period, special sea trials instrumentation is installed, final housekeeping items are completed, the ship is loaded for sea, and all work is completed. Following dock trials, a dockside "fast" cruise by the ship's crew, and, with permission of higher authority, sea trials are conducted.

Between sea trials and ship completion, sea trials deficiencies are corrected to the extent permitted by the schedule. Typically, all major items are completed, even if a schedule slippage is necessary.

D. OTHER CONSIDERATIONS

The overhaul sequence described is typical of that used by Mare Island and other shipyards for submarine overhaul scheduling purposes. Minor variations in the sequencing of events do occur, however. As an example, on recent ships at Mare Island, reactor plant fill has been intentionally delayed until after undocking. Similarly, the durations between the major key events discussed are subject to variation not only by ship type but according to current management philosophy. The latter consideration will be more fully developed in Chapters IV and VI.

IV. DEVELOPMENT OF THE CONSTRAINTS

A. PURPOSE

This chapter will present a detailed development of the environmental constraints under which production management at Mare Island is practiced. In order to realize the importance of these constraints, however, the reader should recall the production management goal stated in Chapter II. Implicit in that goal were the four variables which must constantly be reckoned with in the production management process: available manpower, authorized work, the schedule and estimated cost. Each of these variables or constraints are controllable to some degree in the short term and they are all interrelated. This chapter describes how the variables are developed and describes the interrelationships. Chapter VI will take the available manpower, schedule, authorized workload and cost estimate as given and further discuss the tradeoffs inherent as schedule adherence is sought simultaneously on several different vessels in a cost-conscious environment. As an aside, the author assumed for purposes of this research that a fifth constraint, physical plant and equipment, remained static. In the day-to-day management perspective of this study, this assumption certainly is valid. In a longer term context, the reader should be aware that variations in this factor, either planned or unforeseen, become relevant.

B. DEVELOPMENT OF THE SCHEDULE

Chapter II discussed the Long Range Planning System (LRPS) technique for determining ship loading and assignments to Mare Island. Chapter III presented a typical overhaul sequence. Yet to be discussed are the determination of overhaul length and Key Event dates for a given ship.

1. Overhaul Duration

Submarine overhaul durations are determined by CNO based upon NAVSEA recommendations and are published, along with ship and yard assignments, in the aforementioned OPNAV NOTICE 4710. Although subject to change, the currently authorized durations by ship class for ships recently overhauling or scheduled for overhaul at Mare Island are:

Type and Class	Duration (mos.)
SSBN 598 Class (five ships)	17
SSBN 608 Class (three ships)	15
SSN 594 Class (two ships)	18
SSN 594 Class (a third ship)	17.5

These durations are those initially authorized and do not reflect extensions granted because of emergent work or schedule slippage. The factors determining these specific durations are discussed in general terms in reference 10 and are amplified below.

In the case of Fleet Ballistic Missile Submarines (SSBN), strategic considerations such as ship commitments to NATO and required number of missiles deployed at a given time as opposed to platforms idle in overhaul or upkeep enter into the overhaul duration consideration. Similar force composition

factors are also considered for nuclear attack submarines (SSN). These factors often serve to give SSN type ships implicit priority in the overhaul environment with the result that, as can be seen from the data displayed above, these ships are generally scheduled for overhauls of the shortest possible duration consistent with the work to be done. For shipyard management, the decision of resource allocation priorities favors the SSBN type ship in compliance with reference 10.

Another consideration which bears heavily upon the determination of scheduled overhaul duration is whether or not reactor refueling is required. Refueling is an extremely time consuming and costly evolution which typically adds about 2 months to the overhaul duration. In addition, the size of the authorized work package during a refueling overhaul is typically much larger because of this available additional time. All of the nuclear submarine overhauls recently performed by Mare Island were of this type and all scheduled through FY77 are of this type.

A third factor considered in overhaul length determination is the size and composition of the remainder of the work package including some allowance for growth (emergent work not identified at the start of the overhaul period). In the case of the older ships which Mare Island is assigned, the work packages and the growth factor tend to be larger than on a newer, perhaps more maintainable, ship. These factors serve to increase the authorized overhaul duration.

Finally, the performance of shipyards in the past for similar types of ships and work packages is considered. This factor's influence is difficult to assess explicitly except to state that the durations authorized reflect what CNO/NAVSEA consider to be an achieveable goal in a well-managed shipyard in the absence of capacity overloading [10].

2. Determination of Key Event Dates

Within 30 days of the initial overhaul assignment (and typically about 1 year prior to ship arrival) an initial PERT network reflecting the overall sequencing of the overhaul is drafted by the Production Department Scheduling Section (Code 377) (see figure 1) for submission to NAVSEA and Strategic Systems Project Office Code 26 (SP26) (the latter for SSBN's only). This initial network is based upon information contained in the particular ship's Overhaul Work Package (OWP), a document prepared under the direction of NAVSEA which lists, by ship system, all the overhaul work identified at that early point in time including planned alterations (shipalts and ordalts). The work contained in the initial OWP is subject to change as will be discussed below in developing the authorized work package. Nevertheless, particularly in the non-nuclear area, there are basic activities which will be conducted on each system during overhaul (ripout of interference components, and repair of critical valves, hull access cuts, etc.) which lend credibility to this early PERT network. Furthermore, the shipyard has enough experience in performing these basic

evolutions on a variety of ship types including similar ships to be able to assign key event dates to this preliminary network. These dates are furnished by Code 377 and approved by the Repair Officer and reflect three basic considerations.

The first, discussed above, is an evaluation of how Mare Island has performed in meeting a particular key event in the past. This analysis is a difficult one which must consider aberrations in past overhauls tending to cloud the "typical" performance as well as an analysis of how projected conditions at the time of the future overhaul are likely to be different. The Repair Officer has available graphic data for past ships indicating the scheduled and actual key event achievement dates for use in this analysis.

The second consideration which the current Repair Officer uses in approving the key event dates is one already reflected in the past key event schedules but subject to continual updating. This is his personal philosophy of scheduling each key event at the earliest possible time. This philosophy, which results in an internal schedule typically two months shorter than the authorized overhaul duration, is based on an acknowledgement that in managing a process as complex as a nuclear submarine overhaul involving thousands of sequentially related operations, a certain percentage, perhaps 15 to 20 percent, of these will, through either personnel shortcomings, material delays, growth, or many other reasons fail to occur on schedule. By scheduling each event at the earliest possible time, the Repair Officer seeks to

force problems to the surface early in order to allow more choice in the execution of available options. As an example, in PERT terminology, if an activity (some production evolution from Event A to Event B) has a slack of 1 week (total duration between Event A and B is three weeks due to other activities starting or ending at those points whereas the activity of concern takes only 2 weeks) scheduling the start of this activity two weeks prior to the occurrence of Event B allows no time for recovery in the event of unplanned slippage. On the other hand, scheduling the event to start as soon as Event A occurs allows the full one week slack for exercising alternate courses of action should something go wrong. Such an alternative might be the connection of a temporary system to replace the system of concern, a reallocation of manpower, or others. An additional benefit derived from this "schedule early" practice is the forced early procurement and staging (inspection,assembly,and inventory on or near the job site) of necessary production materials since the material procurement and staging timetable is related to key event date. This "schedule early" philosophy is an extremely important aspect of the entire production management process at Mare Island and will be discussed further in Chapter VI.

Once the Repair Officer has approved the Scheduling Section's key event dates, the preliminary PERT networks are prepared. The activity durations on these networks, by virtue of the way the key event dates were derived, reflect

primarily past experience and thus assume normal levels of manning. They also reflect the normal shift requirements, specifically excluding overtime and holiday time.

Next, the Scheduling Section (Code 377) prepares more detailed system-by-system networks reflecting the approved key events as discussed above for use at the job scoping conferences at which the results of the Planning Department's job estimates are integrated with Production Shop inputs to develop initial cost and time estimates. These "will-cost" advanced planning manday estimates will be discussed more fully below under the development of the cost and manpower constraints. The system-by-system networks prepared at this time are normally not subject to further updating.

As the alteration package is approved, as the ship's Commanding Officer's work list is approved, and as the results of pre-arrival ship checks and pre-overhaul tests (see Ref. 8) are processed, the scope of known work will change. At ship's arrival minus 120 days (A-120) an updated list of major overhaul milestones and associated dates is submitted to NAVSEA reflecting these changes and the philosophy discussed above. This listing is updated every 30 days in compliance with the overhaul contract thereafter and represents the major vehicle by which changing key events are promulgated. The final major change to this listing occurs shortly after the Pre-Arrival Conference (A-90 days) at which the shipyard presents cost and manday estimates to the Type

Commander. Based on these estimates, further work may be added or work may be deleted which may impact slightly the key event schedule. Normally, however, except for unusual growth or major emergent work late in the overhaul, the key events established after the Pre-Arrival Conference are those to which the shipyard production process is keyed. The impact of growth and late emergent work will be discussed in the next section on work package determination.

C. DEVELOPMENT OF THE WORK PACKAGE

Although, given the overhaul duration, the shipyard has considerable control over the determination of key event dates, this degree of shipyard control does not exist in the formulation of the work package, which is done entirely by external agencies albeit with the input of the shipyard. There are three primary sources of external input to the authorized work package for a given ship. These are alterations (shipalts, ordalts) and alteration and improvement (A&I) items, general and specific ship system overhaul requirements, and the ship's work list submitted by the Commanding Officer. Each is discussed below.

Shipalts are classified into one of four different types:

Title "A" - Alterations required for certain ships undergoing construction or conversion. They are authorized by NAVSEA and funded using SCN funds as an investment. Upon expiration of SCN funds, Title "A" shipalts may be classified as Title "K" (see below).

Title "D" - Alterations equivalent-to-a-repair. They are authorized by Type Commanders and funded under O&MN funds as an operating expense.

Title "F" - Alterations capable of accomplishment by Forces Afloat without special program material. Funded by the Type Commander O&MN funds.

Title "K" - All other alterations approved and funded by NAVSEA using OPN funds.

The preliminary (planning version) of a submarine's OWP is issued by the Submarine Planning and Engineering for Repairs and Alterations Program Officer (PERA (SS)) about 18 months prior to the ship's arrival. The alteration portion of this publication consists of a breakdown into nuclear and non-nuclear sections and a further breakdown by Title "K" and Title "D" and "F" alterations. The source of this preliminary information is, for Title "K" alterations, the NAVSEA Advanced Planning letter (issued about A-24 mos) which lists those Title "K" shipalts and ordalts for which funding is tentatively planned by NAVSEA during the forthcoming overhaul subject to availability of material. Guidance on Title "D" and "F" alterations to be included in the preliminary OWP is provided to PERA (SS) by the Type Commander.

This preliminary OWP listed is further refined by NAVSEA with the issuance of the "180 day letter" at A-6 months. This letter modifies the information contained in the Advanced Planning letter and constitutes authority for the shipyard to proceed with planning for the Title "K" shipalts and ordalts

listed, including material procurement. Similarly, for the Title "D" and "F" shipalts, the Type Commander provides PERA (SS) an updated version of the preliminary OWP listing following a review of that listing by ship's force to confirm alteration status and a review of material and funding availability by the Type Commander. This updating normally occurs at the pre-arrival conference at about A-90 days. This updated OWP listing is used by the shipyard as authority to plan and order material for the listed Title "D" and "F" alterations.

The methodology for inclusion of Type Commander Alteration and Improvement (A&I) items into the preliminary and subsequent versions of the ship's OWP is identical to that for Title "D" and "F" shipalts. A&I items differ from shipalts primarily in their definition: they constitute minor Type Commander issued and funded (O&MN) inspections, modifications, or repairs which do not qualify as alterations in accordance with the definition of Reference 10.

Ordalts, NAVSEA-funded alterations to the equipment comprising the submarine fire control and weapons suit, are authorized with the Title "K" shipalts in the 180 day letter discussed above.

The general and specific ship system overhaul requirements are included in the preliminary OWP by PERA(SS) and are derived from the requirements of the General Overhal Specifications (GOS) for the ship class involved and in addition may incorporate special Type Commander requirements. These

requirements include statements like "sandblast and represerve surfaces of the hull and external tanks" and form the basis for a large percentage of the total non-nuclear work package on a given ship.

Repairs not specifically covered within the defined scope of the OWP ship system requirements discussed above but desired by the ship's Commanding Officer may be included in the OWP by two methods. Prior to publishing of the preliminary OWP issue, repairs deferred for depot level accomplishment under the Maintenance and Material Management System Maintenance Data Collection Sub-system (3M/MDCS) are automatically incorporated into the OWP by PERA(SS). After this one-time update by PERA(SS), all further repairs desired by the Commanding Officer must be submitted to the Type Commander for approval. Typically, a "First Supplemental Work List" is submitted by the Commanding Officer in this fashion at about A-9 months. This work package and subsequent supplements, after approval by the Type Commander, become authority for the shipyard to commence detailed planning and material procurement on the included repair items.

The shipyard formal input to the process described above is generally limited to communications with the Type Commander, normally at or before the pre-arrival conference, as to work recommended by the shipyard (based on pre-overhaul shipchecks, tests, etc.) but not currently authorized by the scope of the OWP. The shipyard is not permitted to solicit work but shares a joint responsibility with the ship Commanding Officer for bringing conditions requiring correction to

the attention of the customer. Because of the shipyard's considerable experience in submarine repairs, this input can be extremely valuable.

The scope of the work authorized by the OWP is finalized at or shortly after the pre-arrival conference with the submission and acceptance of the shipyard's initial cost and manday estimates (see section on Costing). Acceptance of these estimates by NAVSEA (Title "K" shipalts/ordalts) or the Type Commander (all other work) or further adjustment of the authorized scope of work to obtain an estimate within the limits of available funds "fixes" the final approved work package which is normally subject to change only due to emergent work submitted as an additional supplemental work list.

D. DEVELOPING THE PERSONNEL RESOURCE CONSTRAINT

Personnel resource level changes are made in response to forecasted workload changes. These forecasts are in turn based upon two different types of work package estimates.

The first type, the Long-range (advanced planning) manday estimate, is prepared prior to determination of the precise work requirements. It may be based upon the requirements of the preliminary issue of OWP, NAVSEA estimates, cost returns from previous overhauls, adjustments to numbers of authorized shipalts, refueling requirements and other factors [7]. This estimate is developed by the Planning Officer and concurred in by the Production Officer. This early estimate, now the Shipyard estimate, serves as the basis for all long-range

workload projections. Forecasted manpower augmentation or reduction requirements by shop are then statistically developed by the Work Status Section (Code 376) of the Production Control Branch. These forecasts, although still tentative, provide management with early warning of major personnel gaps or excesses and permit orderly planning of corrective action. Because of lead times involved in changing the labor force, this manday figure is used as a basis to commence workforce adjustments. The actual lead times vary from trade to trade and in fact tend to "smooth" out what might otherwise appear to be discrete adjustments in the labor base.

Short range manday estimates ("should cost") are developed by the Job Planning Branch (Code 230) of the Planning Department as detailed work requirements become known. For example, after the 180 day letter, short range estimates of shipalts and ordalts can be prepared. The estimating procedure, which will be discussed in more detail under Costing, considers historical data, available drawings, engineered standards, pre-overhaul test and inspection reports, results of shipchecks, shipalt scope sheets and data in ship's work requests. The result is a planner's issued manday estimate, by shop, of what the given work item should cost. This figure is adjusted by the Planning Department Submarine Type Desks (Code 211/214) by increasing it by a reserve factor (greater than 1.0) to account for historical growth within the OWP authorized scope of work for the system under

consideration. The Work Status Section (Code 376) and Advance Planning Section (Code 227) then apply a shop or indirect shop/code (respectively) performance factor to the estimate. These factors (greater than 1.0) reflect the effect of prior shop/code or indirect labor performance in completing work at the planner's issued manday figure.

The result of the above short-range estimating process is a final projected "will-cost" estimate by shop for the given work item. From the sum of the short-range forecasts by shop over all authorized work items (after the pre-arrival conference adjustments are made) a total ship final projected manday cost can be determined. This manday figure is an input to the cost estimating procedure below and can also be used to manage the manday costs and ship manning during the overhaul as will be discussed in Chapters V and VI.

E. COSTING-DEVELOPING THE SALES ESTIMATE

Although the cost estimating procedure is a direct extension of the labor forecasting procedure described above, the reader may benefit more from a description of the costing process if a brief review of the shipyard's overall financial environment is presented first.

Mare Island, as are all Naval Shipyards, is a Navy Industrial Fund (NIF) activity. The Navy Industrial Fund, in turn, provides a revolving type of working capital account for each associated activity. For example, funds expended for labor and materials during an overhaul are withdrawn from this fund at the time they are expended, and replenished by

periodic customer billings. NIF activities endeavor to operate with neither profit nor loss during a budget period (fiscal year) and are restricted in the amount of retained earnings they can carry from one fiscal year to the next. This limit is currently 0.5 percent of the total annual dollar value of the shipyard's business. This limitation and operating philosophy both serve to place great pressure upon the cost estimating process for accurate predictions and, given a cost estimate, upon cost controls to stay within the estimate so as to insure neither profit nor loss. Interestingly, however, this system removes the incentive to minimize costs normally present in a profit-oriented accounting system. The emphasis in NIF accounting is thus more on accurate prediction of actual performance than it is on optimizing actual performance. Pressures for cost minimization come primarily from the customer and comparison of costs incurred with other shipyards. Given this background, the cost estimating procedures and philosophies will be discussed.

There are two significant points in time at which sales estimates are particularly important. The first is at the pre-arrival conference where the shipyard presents the Type Commander or NAVSEA (depending on the work item) with the total initial sales estimate (to be discussed below) for all work items under consideration plus the projected Ultimate End Cost. These figures enable the Type Commander or NAVSEA to adjust the size of the work package in response to estimates lower or higher than expected. Once these work package additions or deletions are made, the final initial sales

estimate dollar and manday figure resulting becomes the basis to which incremental cost increases as new work is authorized are added to keep tally on the total estimated dollar costs as of any point in time. This procedure continues until the 50 percent completion point in the overhaul, at which time the shipyard submits to the Type Commander (and NAVSEA) the fixed price offer. The fixed price offer is the shipyard's estimate in dollars and mandays of what will be required to complete the work authorized at that time. This estimate represents a commitment on the part of the shipyard to complete the work package at that price and, if accepted by the Type Commander (or NAVSEA), becomes binding on the shipyard. Although the schedule duration is not an explicit part of the commitment, the fixed price quoted assumes the schedule will be met. Furthermore, any new work emerging after fixed pricing becomes the subject of Type Desk negotiation with the Type Commander as to cost and schedule impact. The shipyard will normally undertake funded new work after fixed pricing with an advisory statement to the Type Commander that the existing schedule could be impacted by the work item.

Any variation between the agreed-upon fixed price and the final actual (return) costs for a particular work package segment is called a "variance" and either adds to (fixed price exceeded cost) or subtracts from (fixed price less than cost) the shipyard's retained earnings account. These fixed price variances are posted to the retained earnings account at the end of each fiscal year. Thus, an ill-considered fixed price or poor performance in completing the availability could

adversely affect retained earnings by a large amount. In turn, large variances in fixed price during a given overhaul may require that the overhead rate applied to subsequent hulls in subsequent years be modified to restore the basic "zero balance" in retained earnings.

The Type Commander either accepts the fixed price proposed by the shipyard or else rejects it and directs that the overhaul be priced based upon mandays and material actually expended. This is known as funding the overhaul on a "cost-reimbursable" basis. NAVSEA [in Ref. 11] discusses the expected shipyard and customer advantages of fixed pricing and states as policy the requirement for shipyards to enter into fixed price agreements with customers to the maximum extent practicable for overhaul work. The shipyard's task in determining the fixed price offer is thus to attempt to fairly price the total known work package, accounting for the fact that fixed price variances can be used to "adjust" retained earnings significantly different from the desired zero balance. Thus, the shipyard, if it has abnormally high retained earnings, may intentionally submit a low offer expecting to lose money on it to adjust the retained earnings balance. The customer, on the other hand, may have to reject an otherwise fair fixed price offer if it exceeds his overhaul funds available for the current fiscal year. This is because accepting the fixed price obligates the customer to identify to the shipyard the source of fixed price funds within 30 days whereas cost-reimbursable funding is normally done on a periodic small deposit basis at the Naval Regional Finance Center, San Diego. Thus,

the entire final billing amount is not required in the latter case until the very end of the overhaul.

The actual mechanics of generating the initial sales estimate for a work item parallel exactly the short-range shop manday forecasting estimate discussed previously and uses that estimate multiplied by a stabilized manday rate to determine the labor and overhead estimate for that shop and work item (Mare Island allocates overhead by direct labor hours expended.) Summing these estimates over all shops gives the total labor and overhead estimate for the work item.

Commencing in Fiscal Year 1977 a <u>material cost</u> factor will also be included in the stabilized manday rate mentioned above. In the interim, material prices are accounted for by multiplying the job planner's best material cost estimate by a material escalation factor which accounts for predicted material price increases and expenditure variations. This figure is then added to the dollar figure for labor and overhead. By summing this combined labor, overhead, and material estimate over all work items, the final initial sales estimate for use at the pre-arrival conference is determined.

The stabilized manday rate used to estimate the initial work item costs remains fixed throughout an availability as a basis for determining actual costs incurred for billing and estimating purposes. Thus, errors in this rate are included in every work item cost estimate and cost calculation. Any actual condition deviations from the conditions assumed in developing this rate are reflected in a gain (loss) due to billing account which is also posted at the end of each

fiscal year to the retained earnings account. Thus, as stated earlier, adjustments to this rate can be used to compensate (on future hulls) for excessive profits or losses on a single hull.

The <u>Ultimate End Cost</u> estimate provided to the Type Commander at the pre-arrival conference is the total initial sales estimate as of that time plus an allowance based upon past overhaul history for new work.

The generation of the fixed price offer is primarily an exercise for the Type Desk Officer in forecasting the remaining materials and mandays necessary to complete the availability since the costs incurred to that date are known. Normally, determining the remaining mandays is the most difficult task. During a recent fixed price determination, the following sources of data were considered in this calculation:

(1) The planner's revised estimates of remaining material expenditures. These are also adjusted by an escalation factor to arrive at the final remaining material estimates.

(2) The Production Department best shop estimates (collected and prepared by the Work Status Section (Code 376)) of the production work remaining on each work item. This item is weighed heavily in the calculation since it includes an implicit measure of shop performance in meeting the planner's issued mandays for the work item and can thus be used to flag either questionable planner estimates (after the fact) or questionable shop estimates.

(3) The actual total manday expenditures cumulative through the estimating date fitted with an expenditure factor

which reflects what was done from that point in the overhaul through completion on previous ships. This method can provide useful best and worst case estimates.

(4) The planner-issued mandays at the estimating date adjusted by a factor to account for historical increases in the amount of mandays issued through the completion of overhaul. This factor is adjusted by the Type Desk Officer's best estimate of shop performance in meeting these estimates to arrive at the estimated remaining production mandays.

(5) The actual total manday expenditures through the estimating date divided by a percentage factor which accounts for the percentage of total overhaul remaining after the estimating date.

Each of these manday estimates (when multiplied by the stabilized manday rate) is added to the remaining material estimate and the actual incurred costs (labor, overhead, and material) as of the estimating date to derive a unique fixed price estimate. These estimates are used as cross-checks on each other. Type Officer judgement and an awareness of the desired fixed price variance resulting from the overhaul determine the final figure submitted to the Shipyard Commander for approval.

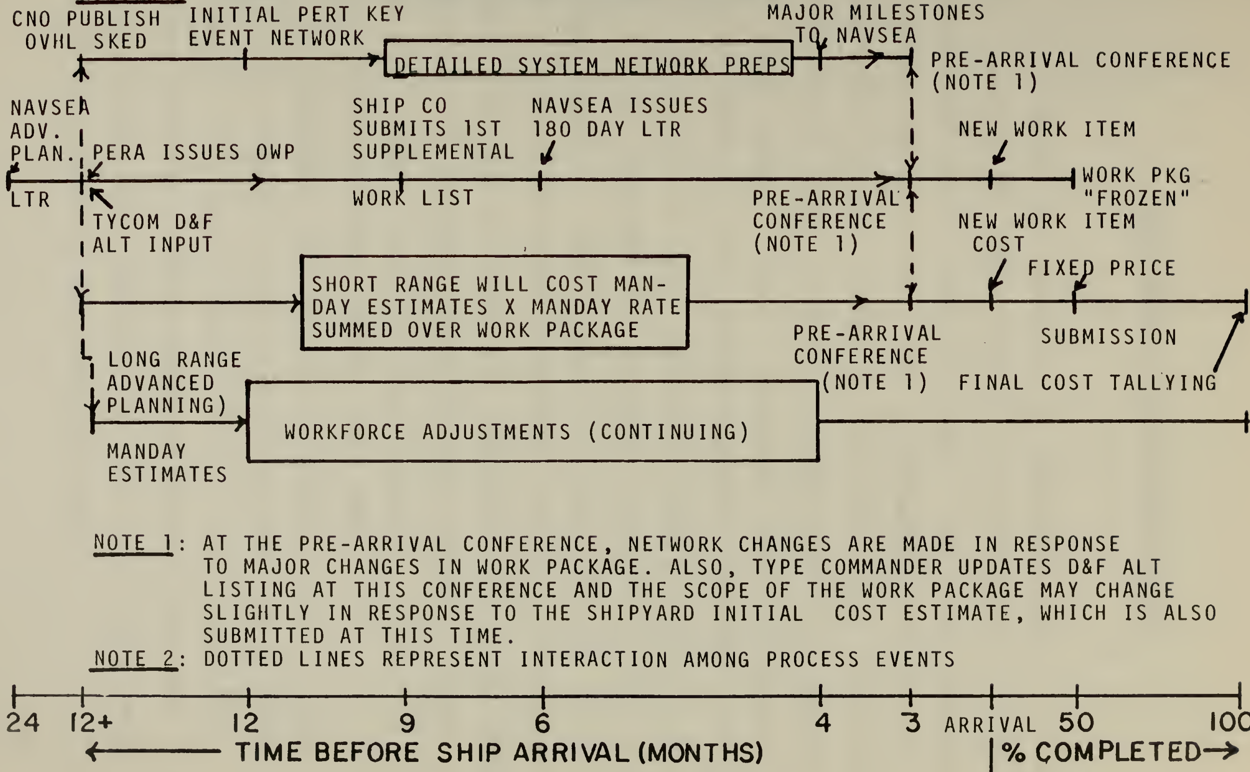
F. SUMMARY

This chapter has developed the basic constraints of schedule, work package, estimated cost, and manpower required for a given ship. The significant points in this developmental

process are summarized in figure 3. A key point to remember is the fact that the work package, while itself undergoing iterative revision, is a key input into the determination of the schedule length, the personnel resource requirements, and the sales estimate. In turn, should the final initial projected sales estimate prove too high for the customer, this may cause a reduction in the scope of authorized work. Considerable discussions typically take place between the customer(s) and the shipyard at the Pre-Arrival Conference (A-90 days) to insure that the proper balance of authorized work and estimated cost are achieved. Also noteworthy are the implications of an ill-conceived fixed price offer on the shipyard's retained earnings balance. Ultimately(through fixed manday rate adjustments on future hulls), the customer bears the cost of any overruns in either schedule or cost because of the requirement that the shipyard "break even" in the long run in the retained earnings account. Finally, the reader should recall that, despite the workload forecasting and personnel resource augmentation techniques discussed, Mare Island has forecast an average shortage of about 650 mandays per day for the remainder of CY 1976. This shortage will be taken as a given factor in the chapters which follow. Similarly, having discussed up to this point the development of the various constraints on a given ship, the author in the succeeding chapters will develop an increasingly multi-ship perspective.

Accordingly, Chapter VI will assume that the initial constraints have been developed as stated in this chapter for each ship in overhaul and discuss possible tradeoffs among them in a multi-ship environment to optimize schedule adherence. But first, the management tools used to monitor the production process must be described. This is the subject of Chapter V.

FIGURE 3. SUMMARY OF CONSTRAINT DEVELOPMENT PROCESS



NOTE 1: AT THE PRE-ARRIVAL CONFERENCE, NETWORK CHANGES ARE MADE IN RESPONSE TO MAJOR CHANGES IN WORK PACKAGE. ALSO, TYPE COMMANDER UPDATES D&F ALT LISTING AT THIS CONFERENCE AND THE SCOPE OF THE WORK PACKAGE MAY CHANGE SLIGHTLY IN RESPONSE TO THE SHIPYARD INITIAL COST ESTIMATE, WHICH IS ALSO SUBMITTED AT THIS TIME.

NOTE 2: DOTTED LINES REPRESENT INTERACTION AMONG PROCESS EVENTS

V. MANAGEMENT TOOLS AND THEIR USAGE

A. PURPOSE

This chapter will describe the management aids in use at Mare Island by the Repair Officer to facilitate his progressing and expediting of production work. The author discovered, in researching this topic, that the management tools used vary considerably from one manager to the next. Thus, this chapter and Chapter VI (which discusses how the information derived from these sources is used to optimize schedule adherence for several overhauling ships simultaneously) represents a "snapshot" of a point in time. The author makes no claim that the aids or uses described will be those used in the future either at Mare Island or other shipyards and does not wish to imply that they have been those historically employed in the past. Rather, these are the tools and techniques used by one Repair Officer at one shipyard during the last quarter of fiscal year 1976. These procedures were developed in late 1972 and have been practiced and refined since then.

The management aids used by the Repair Officer at Mare Island are products of four distinct sources: the Shipyard Management Information System (MIS), the Mare Island Non-Nuclear Composite, locally generated graphs, forms, and written reports, and verbal status reports. These primary sources of information are discussed below.

B. THE SHIPYARD MIS

The Shipyard MIS is a computerized management information system which takes into consideration all aspects of industrial management: forecasting, planning, scheduling, production, and evaluation. The system software, designed around a Honeywell 6060 computer system, was developed under the direction of Naval Sea Systems Command and is continually modified to produce report forms of use to a broad spectrum of system users. The Shipyard MIS is presently installed and in use at all Naval shipyards but some latitude exists at the shipyard operating level as to which MIS reports are used and how they are used. The Shipyard MIS relies on an integrated data base which is organized into four basic subsystems which in turn group 13 available response applications by management functional category (see figure 4). Within these various response applications some 400 different reports are available. This research concerns itself only with those MIS reports used by the Repair Officer, however, and only those will be described below. The reader interested in a more detailed study of the organization and outputs of the Shipyard MIS may wish to consult reference 12, from which the above general description was derived, or reference 13,which is the standard users' manual for this system.

C. THE NON-NUCLEAR COMPOSITE

In addition to the Shipyard MIS, Mare Island has developed an internal computer-based system for maintaining listings

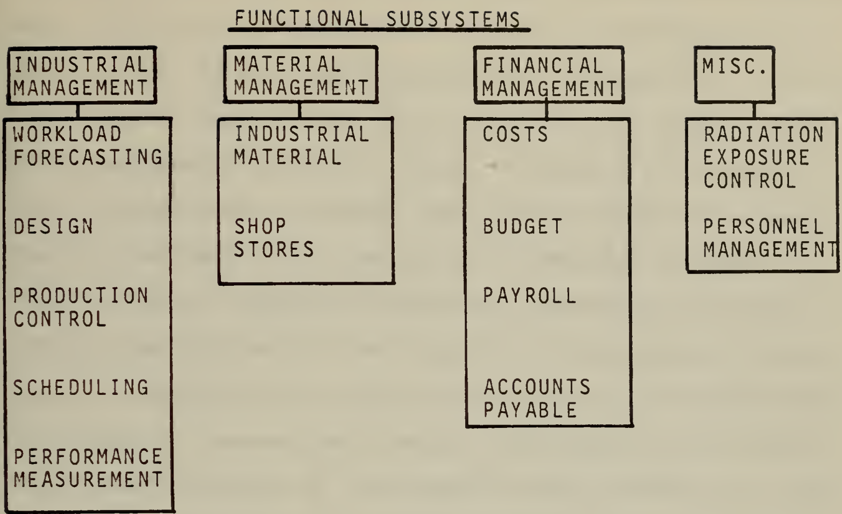


FIGURE 4. Shipyard MIS Organization (Ref 12).

by ship of all outstanding work in the non-nuclear production area. This system, described in detail in reference 14, is known as the Non-Nuclear Composite and is managed by the Ship Work Control Center (Code 365) to provide, on demand, convenient management reports to assess the status of remaining work on non-nuclear systems. The author learned in conducting this research that some of the information provided by the Non-Nuclear Composite duplicates information available through the Shipyard MIS and that Mare Island was in the process of eliminating the duplication in favor of the Standard MIS outputs. Because the Standard MIS reports do not presently permit sorting of job order KEY-OPS (a KEY-OP is a distinct portion of work on a system written into a job order) by system and applicable KEY EVENT, the author believes that this single feature will continue to make the Non-Nuclear Composite reports attractive as a management aid even after all duplication is eliminated. Because the MIS production control (PC series) reports are organized around KEY-OPS, the basic task in eliminating duplication between the two systems is to establish a one-to-one correspondence between KEY-OPS and other classifications of work authority documents presently accounted for by the Non-Nuclear Composite (see below).

The Non-Nuclear Composite is a production-oriented system which keeps track of the numbers of various types of source documents outstanding on a given ship. These source documents, a complete listing of which can be found in reference 14, are each a source of some kind of shipyard action on the

system involved. This action may involve clearing an emergent deficiency, performing an item of known work, conducting a non-destructive test, clearing a valve lineup to restore the system to a normal lineup, or many others. Each source document is assigned to a responsible code for action and is identified in addition by a unique report number, system, Key Event, compartment, deck, and location.

There are ten different sort modes available for the data contained on a given ship [see Ref. 14]. Those used by the Repair Officer will be discussed below. The non-nuclear composite contains a strong inherent managerial accountability and control device in its requirement for Shop Supervisors to verify completion of the action called for by a given source document and to sign the Code 365 copy of that document before the document can be cleared from the computerized system reports. This requirement, self-imposed by the shipyard, serves to increase supervisory involvement, knowledge, and accountability for work status determination and lends considerable credibility to the Non-nuclear Composite reports. Through the process of "starring," to be discussed below, the composite reports also acquire an official status.

D. OTHER SOURCES OF INFORMATION

The two other basic sources of management information for production control and monitoring--locally generated graphs, forms, and written reports and verbal reports--will be expanded upon as the actual information in these classifications is discussed.

E. MANAGEMENT AIDS USED TO MONITOR AND CONTROL PRODUCTION AT THE REPAIR OFFICER LEVEL

1. MIS Outputs

The only MIS output routinely used by the Repair Officer is the Daily Force Distribution Ship by Shift Report, PF-102B (see figure 5). This report contains, for each shop, shift, and ship availability type listed, total mandays worked, overtime mandays worked, and mandays forecast for the report date.[3] Three availability types codes are commonly used: nuclear (NU), non-nuclear (NN) and refueling (RF).

The key to interpreting this report is listed along the bottom of each page, of which figure 5 is a sample. Under the column labeled "Shift" are shift numbers, "1" being the day shift, "2" being swing shift, and "3" being graveyard shift. The entries horizontally opposite the shift number "1" represent the total mandays expended by all shops (far left hand column) or specific individual shops on that ship availability on the day in question. The next two rows, labeled "WF 1" and "Shop 1" respectively, show the mandays actually expended in waterfront and shop work for that availability. These two figures sum to the total listed in the previous row. The row labeled "OT MD" shows overtime mandays worked. The "WFT MD" and SHOPT MD" rows list total waterfront and in-shop mandays. The "TRT MD" row shows mandays expended in training. "TOT MD" reflects the total mandays expended by the shop (or all shops) during the given day, a figure that can be directly compared with the row labeled

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[3] Availability type refers to discrete phases within a given overhaul, typically each with a separate managing organization answering to the Production Officer.

PF-1028

Figure 5.

DAILY FORCE DISTRIBUTION REPORT, SHIP BY SHIFT

MARE ISLAND NAVAL SHPYRD
ISSUE DATE 05 MAY 76
DATA DATE 05 MAY 76

SHIP	SHIFT	ALL SHOPS	06	11	17	23	26	31	36	38	41	51	56	64	67	71	72	81	99	05	19	24	32	33	34	35	39
FLASHER NN	1	142		5	11		4	6	9	37		6	17	15	5	8	3		4		6	26		7		1	1
SS N61 3	WF 1	59		5	7		2		2	12		4	17			6	3		2								1
	SHOP 1	83			7		2	6	7	26		12	1	15	5	2			2		6	26		7		1	
	2	60		3	4		4	5	3	17		9	2		2	6	5		2			5		2			
	WF 2	35		3	2		3			8		5	2			6	5		2								
	SHOP 2	25			2		1	5	3	9		4			2							5		2			
	3	31			1		2		2	11		10	2				2		1			3				3	
	WF 3	27			1		2			10		9	2				2		1								
	SHOP 3	4							2	1		1										3				3	
	OT MD																										
	WFT MD	121		8	10		7		2	29		18	20			12	10		5								1
	SHOPT MD	113		1	8		3	10	12	36		17	1	15	7	2			2		6	34		9		4	
	TRT MD																										
	TOT MD	233		9	18		10	10	14	65		35	21	15	/	14	10		7		6	34		9		4	1
	LOAD MD																										
	WLF	268		12	24		11	8	12	64	1	38	31	11	10	24	15		7.								
WASHINGTONNU	1	196	6	7	8		3	10		39		23	54	2	11	1	28		4	30		2	46	2	1	3	32
SSBN 598	WF 1	96		4	3		2	2		14		18	29			1	19		4								
	SHOP 1	100	6	2	5		1	8		25		6	25	2	11		9			30		2	46	2	1	3	32
	2	88			1		1	7		17		17	22		9	1	14			15		1		1			17
	WF 2	47								11		13	14		2		7										
	SHOP 2	36			1		1	7		1		4	8		7	1	7			15		1		1			17
	TR 2	5								5																	
	3	82	1	1	5		4	3	1	27		8	12	2	9		9		1	14						1	13
	WF 3	47		1	2		3			12		8	9	2	2		8		1								
	SHOP 3	30	1		3		1	3	1	10			3		7		1			14						1	13
	TR 3	5								5																	
	OT MD	1								1										7							12
	WFT MD	189		5	5		5	2		38		38	51	2	4	1	34		5								
	SHOPT MD	166	7	2	9		3	18	1	36		10	36	2	25	1	17			59		3	46	3	1	4	62
	TRT MD	10								10																	
	TOT MD	365	7	8	14		7	20	1	83		48	88	4	29	2	51		5	59		3	46	3	1	4	62
	LOAD MD																										
	WLF	267	7	14	6		13	16	1	52	1	52	48	5	8	1	36		7								

DISTRIBUTION DISPATCHER SHOP-SHOP WORK SHOPT-SHOP WORK TOTAL TR-TRAINING TRT-TRAINING TOTAL
WF-WATERFRONT WFT-WATERFRONT TOTAL WLF-WORKLOAD FORECAST LOAD MD-SCHEDULE LOAD PAGE 8

"WLF". The latter row contains the Work Status Section (Code 376) manday forecast for the day based upon the short-range manday estimate previously discussed and the internally scheduled overhaul length plus historical ship manning trends (to be discussed further below). Thus, from this report the Repair Officer can determine at a glance for a given ship whether non-nuclear manning, either in-toto or by specific shop, met, exceeded, or fell short of the projected expenditure rate. He can also determine, if desired, whether non-nuclear manning efficiency is better than or worse than nuclear and can assess the need for reallocation of personnel resources either from one ship to another or from nuclear to non-nuclear availabilities within the same ship. (Mare Island has a limited number of workers qualified to perform either nuclear or non-nuclear work.) Personnel reallocations will be discussed further in Chapter VI.

Included as part of the PF102B report is a summary for all ships of the total manday expenditures in each category by shop (not shown) and summary (figure 6) which presents a total for all ships of the mandays expended in each availability type. This summary data is also of use in determining if reallocations of personnel are appropriate.

2. Non-Nuclear Composite Outputs

The Non-nuclear Composite outputs comprise the heart of the Mare Island production management system. Because of the situational nature of their use, however, the author has attempted to present them in the context of their normal employment.

PF1028 DAILY FORCE DISTRIBUTION REPORT SHIPWORK SUMMARY TOTAL BY SHOP DATA DATE 05 MAY 76

	ALL SHOPS	06	11	17	23	26	31	36	38	41	51	56	64	67	71	72	81	99	05	19	24	32	33	34	35	39
TOT NU MD	554	18	19	17		13	26	1	99		73	143	10	42	5	71		17								
TOT NU WLF	530	16	31	13		27	28	1	73	1	79	124	16	22	4	76	1	18								
TOT NN MD	2823	8	219	122	17	195	278	150	449	37	367	375	148	54	146	181		76								
TOT NN WLF	3024	6	221	150	12	200	306	157	436	48	338	448	140	63	158	241	1	99								
TOT RF MD	61	1	8	2		11			22			2				13		3								
TOT RF WLF	51	2	7	2		8	2		25		1	2	1			7		4								
GRAND TOTAL MD	3438	27	246	141	17	219	304	151	570	37	440	520	158	96	151	265		96								
GRAND TOTAL WLF	3615	24	259	165	12	235	336	158	534	49	418	574	157	85	162	324	2	121								
OVER MANNED MD		3			5				36		22		1	11												
UNDER MANNED WLF	177		13	24		16	32	7		12		54			11	59	2	25								

Figure 6. Daily Force Distribution Report, Ship by Shift, Summary.

a. PCL 216B Tape

Daily, prior to the start of the working day, the Repair Officer receives a complete PCL216B computer runoff for each ship (see figures 7, 8, and 9). This runoff, or "tape," as it is called, presents a summary of outstanding source documents by category and responsible code (figure 7), by system, category, and cognizant code (figure 8), by key event, category, and cognizant code (figure 9), and a gross summary by compartment (also figure 9). A copy of this same report is presented to each group superintendent daily as well. The PCL216B format does not lend itself to meaningful analysis by itself;other factors, such as the proximity of a key event, status of a given system, recent source document clearance trends, and production bottlenecks resulting from overmanning in a given compartment must be known to assess the totals listed correctly. With this kind of data (to be discussed below), the Repair Officer can review this report and determine potential trouble areas and take the necessary action to redefine shop priorities to eliminate bottlenecks, direct more manpower to a given system, or hasten clearance of all items outstanding for a given key event. The tradeoffs involved in this process are the subject of Chapter VI. The PCL216B report is thus a good day-to-day monitoring and control aid which can assist in determining the need for resource reallocation.

As an example of how the PCL 216B tape might be used in a hypothetical case, suppose that shop 38 (outside machine shop) is behind schedule in completing their assigned

PCL2168 USS GEORGE WASHINGTON SSBN 598 NON-NUCLEAR COMPOSITE OF 21 MAY 76

Figure 7. SUMMARY BY RESPONSIBLE CODES AND CATEGORIES

CATEGORY	911	917	926	931	936	938	941	951	956	964	967	971	972	133	190	210	290	330	365	098	OTHR	TOTAL
AI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	262	262
CFC	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	2
OCI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	6
OFI	2	0	0	3	0	0	0	1	1	0	0	1	0	2	0	5	0	0	0	0	0	15
OPTI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
OSFR	1	0	0	0	0	3	1	1	12	0	0	6	0	0	0	3	0	1	0	12	10	50
OSFW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	170	0	170
FI	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	3	0	0	0	0	1	7
MISC	0	0	0	0	0	1	0	1	0	0	0	0	0	15	0	5	0	0	0	9	0	31
OCI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
POIS	11	2	2	22	3	12	3	10	9	2	1	0	1	13	0	0	3	0	0	0	4	98
PDLM	43	1	3	28	13	13	5	25	29	5	2	0	3	2	0	0	0	0	0	0	4	176
PEIS	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	2	5
PRT	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
RI	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	3
SWJC	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3
TDR	3	1	0	0	0	8	0	44	21	0	0	0	0	0	7	0	349	0	1	68	0	502
TDSS	77	0	0	0	29	143	0	12	182	0	10	0	0	0	5	0	40	0	0	4	1	503
TP	17	0	0	20	13	65	0	78	49	1	2	0	6	4	0	0	52	0	0	0	0	307
TPC	0	8	0	0	62	22	0	33	10	0	100	0	1	0	133	0	0	0	0	0	1	370
WP	72	26	0	0	37	353	2	367	430	0	32	0	0	0	2	0	5	1	7	348	0	1682
WPSS	50	1	0	0	37	228	1	33	123	0	1	0	0	1	0	0	1	5	1	18	0	500
WPTA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56	0	0	0	56
TOTAL	278	39	6	74	194	848	12	605	870	8	148	7	11	42	147	17	450	63	9	638	286	4752

Figure 8. SUMMARY BY RESPONSIBLE CODES AND SYSTEMS

SYSTEM		911	917	926	931	936	938	941	951	956	964	967	971	972	133	190	210	290	330	365	098	OTHR	TOTAL
A	TOT	17	8	0	20	75	83	0	110	59	1	102	0	7	4	132	0	49	0	0	0	1	668
	WKPM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	OEF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TP	17	0	0	20	13	61	0	77	49	1	2	0	6	4	0	0	49	0	0	0	0	299
	TPC	0	8	0	0	62	22	0	33	10	0	100	0	1	0	132	0	0	0	0	0	1	369
	TPO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	RET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	AI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PLNG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	OTHR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ABE	TOT	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	WKPM	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	OEF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TPO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	RET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	AI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PLNG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	OTHR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ABT	TOT	0	0	0	0	0	17	0	2	13	0	0	0	0	5	0	0	0	1	0	1	0	39
	WKPM	0	0	0	0	0	12	0	2	9	0	0	0	0	0	0	0	0	1	0	1	0	25
	OEF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TPO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	RET	0	0	0	0	0	5	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	9
	AI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PLNG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	OTHR	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	5
AC/ASW	TOT	3	0	0	1	0	12	0	0	17	0	0	0	0	0	0	0	0	1	0	4	0	38
	WKPM	2	0	0	0	0	8	0	0	12	0	0	0	0	0	0	0	0	1	0	4	0	27
	DEF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TPO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	RET	1	0	0	0	0	3	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	9
	AI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PLNG	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	OTHR	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
ACSB	TOT	0	2	0	0	0	0	0	69	0	0	1	0	0	0	0	0	2	0	0	3	0	77
	WKPM	0	2	0	0	0	0	0	57	0	0	1	0	0	0	0	0	0	0	0	2	0	62
	OEF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TPC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TPO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	RET	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	2	0	0	1	0	11
	AI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PLNG	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4
	OTHR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Figure 9. SUMMARY BY RESPONSIBLE CODES AND KEY EVENTS

KEY EVENT		911	917	926	931	936	938	941	951	956	964	967	971	972	133	190	210	290	330	365	098	OTHR	TOTAL
WT	TOT	1	0	0	0	16	2	0	6	0	0	0	0	0	0	3	0	0	0	0	2	0	30
	WKPM	0	0	0	0	2	2	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	10
	DEF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
	TP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TPC	0	0	0	0	14	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	17
	TPO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	RET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	AI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PLNG	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	OTHR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NUMBER OF ITEMS BY COMPARTMENT

AMR 1	AMR 2	BOW	ENGRM	MSL	OPS	RC	SS	VAR	AMS	MISC
2	19	82	1080	373	298	46	12	52	551	2237

work in USS GEORGE WASHINGTON (SSBN 598). Suppose also that one engine room system in that ship in which shop 38 is still heavily involved, the air conditioning auxiliary seawater system (AC/ASW), is due for strength and tightness testing in two weeks. By a review of figures 7, 8, and 9, the Repair Officer observes that shop 38 (shown as '938' in column headings) has 848 composite items outstanding on WASHINGTON, that 24 of these are in the AC/ASW system, and that there are a total of 1080 items outstanding (for all shops) in the engine room. Now, if recent composite item clearance trends for other shops working in the engine room have been satisfactory and if engine room manning has been heavy, the Repair Officer might elect to redefine priorities such that physical interference from other shops is reduced if the shop 38 supervisor feels that this is the problem. The Repair Officer might also suggest to the shop 38 supervisory personnel that more emphasis be placed on the AC/ASW system work. By monitoring the PCL 216B reports in subsequent days, the Repair Officer can determine whether his actions have been effective.

b. PCL 217E Tape

As a key event scheduled date becomes very close, managerial attention shifts from numbers of source documents outstanding to the specific documents outstanding. Control is effected through use of the PCL 217E runoff (tape) which presents, by responsible code, a detailed listing by system, category, and report number of all documents outstanding for the key event (see figure 10). As the key event approaches,

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PCL217E                  USS GEORGE WASHINGTON SSBN 598       NON NUCLEAR COMPOSITE OF 05 MAY 76
                                   Figure 10.  KEY EVENT BY RESP CODE BY SYSTEM BY CATEGORY BY REPT NO

SERIAL C   KEY   RESP                       REPORT    REWK DATA   ITEM/ ------LOCATION-------  REPORT   RESP   DATE    SCHED    KEY    SPECIAL
NUMBER D  EVENT  CODE   SYSTEM   CAT   NUMBER    T-C-SHOP    WK CL COMPT  DECK  P/S  FRM   CODE    CODE   GEN     COMPL   EVENT   CODING

03160  0  CL      0290  A         TP    2670800                                              0290    0290   01176   06186    CL
       1        300KW MOTOR GENERATOR SET OPERATIONAL TEST SS18

01079  0  CL      0290  A         TP    2675000                                              0290    0290   11195   02047    CL
       1         BATT ELECTROLYTE AGITATOR ELECTRICAL OPS (DD32)

02021  0  CL      0290  C         TDR  0CD0292                  ENCRM  LL         VAR        0290    0290   12195            CL
       1        RRR 79-SC-763,764,765,766,767,768.  REINSTALL ON KO 614     <SS18>

03519  0  CL      0290  C         TDR  0000723                  ENCRM  LL     X   065        0290    0290   01296            CL
       1        RIP REPAIR NO.1 &2 SURGE TANK MECHANICAL INDICATORS. FLOAT SWITCHES &
       2        SIGHT GLASSES      <SS18>

03599  0  CL      0290  C         TDR  0000750                  ENGRM  U/L    X   065        0290    0290   02026            CL
       1        DISCONN PIPING & RMV CONDENSATE GAGES AS PER TO CALIB KO 2001226 INSTL
       2        KO-3D01326 <DC-14>

08306  0  CL      0290  ICA       TDSS 0000542                  MSL    ML     S   044        0290    0290   04286            CL
       1        <TK WK> SHIP/ALT SSBN 1263D  RMV FOR DISPOSITION F.O.  EXPANSION
       2        TR LVL INDICAT CBLS & COMP AS PER ATTACH K.O. #1D7 1EA PC-3M
       3        1EA PC-1K. 1EA PC-20 PLN #4662082-128 & 2195963-SHT1-14A&D <CM17>
       4        *-N/A          JO-1659843704-107                     SUPER-SELBX

08307  0  CL      0290  ICA       TDSS 0000543                  MSL    ML     S   044        0290    0290   04286            CL
       1        TK WLK SHIP/ALT SSBN 1263D INSTALL THE FOLLOW NEW COMP FOR FO
       2        EXPANSION TK LVL IND:1> RECEIVER <IEA><2> LVL TRANS <3EA><3>
       3        CBL ASSEMNBLIES <2EA> PLN #4662082-12B & 4662783-8 <CM17>
       4        *-N/A          JO-1659843704-307                     SUPER-SELBX

08308  0  CL      0290  ICA       TDSS 0000544                  MSL    ML     S   044        0290    0290   04286            CL
       1        SHIP/ALT SSBN 1263D RMV FOR DISPOSITION F O COLLECT TR LVL
       2        INDICAT CBLS & COMP AS PER ATTACH K.O. #108  1EA PC-3L ELECTRODE
       3        F.O. COLLEC TK. 1EA-PC-1L MEASURING UNIT. 1EA-PC-2C INDICAT UNIT
       4        LEAD #C-4TK1-2. C-4TH1-B. C-4TK1-4.C-TH1-20. PLN #662082-138 &
       5        2195969-SHT1-14A315D <CM17>
       6        **-N/A         JO-1659843704-108                     SUPER-SELBY

08311  0  CL      0290  ICA       TDSS 0000545                  MSL    ML     S   044        0290    0290   04296            CL
       1        SHIP/ALT SSBN 1263D. INSTALL THE FOLLOW  NEW COMP FOR F O COLLECT
       2        TK VLV IND.<1> RCVR<1EA><2> LVL TRANSMITTERS <SEA><3> CBL
       3        ASSEMB<8EA> PLN #4662082-138 & 4662783-7  <CM17>
       4        *-N/A          JO-1659843704-300                     SUPER-SELBY
```

copies of this tape are made available to the Repair Officer and group superintendents on a daily basis. These reports, together with information available to these parties through daily reports by their subordinates, form a complete and up-to-date picture of the remaining items necessary to prepare for the key event and permit managerial action to be focused upon these items. The Repair Officer and Group Superintendents meet daily early in the morning with the Production Officer where status of the items may be discussed, and necessary actions taken to resolve the remaining items in the quickest fashion possible. The goal of these meetings, facilitated by a document like the PCL 217E tape, is to get all involved activities (codes) moving in the same direction in a coordinated manner.

As an example of how the 217E tape is read, consider the core load (CL) key event. A portion of that section of the 217E tape is shown by figure 10. From this figure, the Repair Officer learns, by shop (in this case, Code 290), the specific items outstanding for that key event. For example, a portion of the test procedure (TP) for the 300kw motor generator operational test remains to be completed (first entry).

As an aside, the convention used for recording dates in this and subsequent non-nuclear composite reports is as follows: of the five digit date entry, the first two digits reflect the month, the second two digits reflect the day, and the final digit is the last digit of the year, e.g., "6" means 1976.

c. PCL 217G Tape

For certain minor key events (electrical switchboard initial lightoff is an example) the work to be completed resides primarily in a single system. In these cases, the Repair Officer requires that the ship superintendent manages preparations for the event using the PCL 217G tape (figure 11) which provides a detailed listing by system, responsible code, and category of outstanding items. The Repair Officer will normally monitor the ship superintendent's efforts in this regard to insure that proper shop support is obtained. Progress towards clearance of items on this tape is normally the subject of verbal or conference type reports to the Repair Officer (discussed below).

Figure 11 might be used as follows in preparation for the undocking (UD) key event (although by no means a "minor" key event in the context discussed above, this event suffices for purposes of illustration if one assumes this key event to involve only the salvage air system). By review of figure 11 beginning with the next-to-last column, the Repair Officer/Ship Superintendent learns that five items in the salvage air (ASS) system remain to be cleared for this key event. Knowing that this key event is scheduled to occur on a given date (available from the system network drawing) the Repair Officer/ship superintendent can assess the level of shop effort and managerial attention which must be expended on the remaining items to insure readiness for the key event as scheduled.

Figure 11. SYSTEM BY CATEGORY BY REPORT NUMBER

SERIAL NUMBER	C D	SYSTEM	CAT	REPORT NUMBER	REWK DATA T-C-SHOP	ITEM/ WK CL	LOCATION COMPT	LOCATION DECK	LOCATION P/S	LOCATION FRM	REPORT CODE	RESP CODE	DATE GEN	SCHED COMPL	KEY EVENT	SPECIAL CODING
03761	0	ASS	AI	0000027			AML	UL	S	054	0133	0214	01196		CR	
	1	ASS 9														
	2	17- ASS 9 PIPE HANGER NOT MADE UP 4 FT BELOW RC STAIRS														
03372	0	ASS	MISC	0000004	B 09		ENGRM				0133	0210			CR	
	1	WORK PERMIT														
	2	S.S. WORK PERMIT ISSUED TO PRODUCTION SHOP WITHOUT CERTIFICATION OOCMEN														
	3	TS ON A NOT-TO-DELAY BASIS PER HP&A MANUAL. CHAP 3 SEC.2. OBTRAIN CERTIF														
	4	JTIFICATION DOCUMENTS AND S.S. WORK BOUNDARIFS FROM CODE 133.11. RECORDS														
	5	SECTION. PRIOR TO RE-INSTALLATION. MAPPING AND QAL PLANS ARE NOT AVAILAB														
	6	LE ASS 11 HULL FASTENERS DELETED FROM PLAN														
00048	0	ASS	POIS	0004716							0260	0210	11125		UD	
	1	COMPARTMENT SALVAGE VALVE (SS-18)														
01488	0	ASS	TOSS	0000068				UL	C	VAR	0290	0956	12295		HO	
	1	RSR PIPE OUTBOARD OF ASS-7 & ASS-8. THE FOLLOWING WILL BE VIOLATED-														
	2	ASS-1015. 1024. 1029. 1012. 6022 & AT ASS-1026. INTERFERENCE-HULL														
	3	ACCESS R.C. (SS18)														
03393	0	ASS	TOSS	0000238			ENGRM	UL	C	070	0290	0956	01316		UD	
	1	ENG RM ACCESS INTERFER DICON OPER GEAR & REMOVE PPG & VLV ASS-12 IN														
	2	ORDER TO ALLOW REMOVAL OF HULL ACCESS REINSTALL KO-321 INSPECT VLV KO211														
03395	0	ASS	TOSS	0000239			ENGRM	UL	C	070	0290	0956	01306		CR	
	1	ENG RM ACCESS INTERFER RSR ASS-11 VALVE DISCON OPER GEAR & REMOVE PPG &														
	2	VLV ASS-11 IN ORDER TO ALLOW REMOVAL OF HULL ACCESS REINSTALL KO-321														
	3	INSPECT VLV KO-211														
03700	0	ASS	TOSS	0000255		A	OPS	U/L	C	049	0290	0956	02036		UD	
	1	RSR ASS-7 & 8 HULL ACCESS ITEM FOR RC <OC-14>														
06551	0	ASS	TOSS	0000425			AMS	UL	S	054	0290	0938	02106		UD	
	1	INTERF. FOR MS-1 REMOVAL R.R.R. VALVE ASS-9 PL-4537525 (JC-32)														
	2	* JO 1659820701-100														
06553	0	ASS	TOSS	0000426			MBT-5	UL	S	054	0290	0938	02106		UD	
	1	INTERF. FOR ASS-9 REMOVAL R.S.R. EXT OPER GEAR & EXT PIPE P-1 FOR ASS-9														
	2	CUT OUT NON PRESSURE HULL ON MBT-5 FOR REMOVAL PL-4537525														
	3	* JO 1659820701-100														
01432	0	ASS	WP	0000120			TUNNE	UL	S	045	0365	0956	02066	03037	CR	
	1	HULL ACCESS- R.C. RSR PIPE PER KO 103A & REINSTALL KO 601 PL4537525-10C														
	2	* RSR JO 2059882521- 103 A SUP. NUGENT														
01866	0	ASS	WP	0000239			MSHIP	M/L	S	045	0365	0956	01066	03037	CR	
	1	RIPOUT INTERF PIPING IN RC TUNNEL AS PER ATTACHED JO 72502-116 REINSTALL														
	2	JO-82502-632 CUT P-13 REF A ELI F-4<P-3 REF B>8 DWNSTRM FAR ENOUGH TO														

3. <u>Locally Generated Graphs, Forms, and Written Reports</u>

The use of locally generated graphs and written reports to supplement the computerized control systems discussed is highly situational in nature. Such "Ad Hoc" techniques have the advantage, however, of being easily established or discontinued when their usefulness is gone and in addition can be easily tailored to the specific requirements of a unique situation. Those discussed below are typical examples.

a. Plot of Total Composite Items by Key Event

As certain major key events approach (typically within 3-4 weeks), Code 365 develops time-plots of the total number of non-nuclear composite items remaining for that key event for certain critical shops [normally shop 56 (pipefitters), shop 38 (outside machinists), and shop 51 (electricians)] (see figure 12 for an example).

These plots provide the Repair Officer and Ship Superintendents with the ability to visually assess progress and determine, based on past and current completion or clearance trends, whether it is likely that the key event can be achieved on schedule. If not, appropriate expediting and resource real-location decisions can be made.

For example, assuming that the reactor plant criticality key event is scheduled to occur on 31 March and that only 50 items may remain on the composite at that time, the Repair Officer, by reviewing figure 12, may sense as early as the third or fourth of the month that unless composite item clearance rates improve dramatically, that date will be

KEY EVENT CR SHIP 613 SHOP 56

TOTAL OUTSTANDING COMPOSITE ITEMS

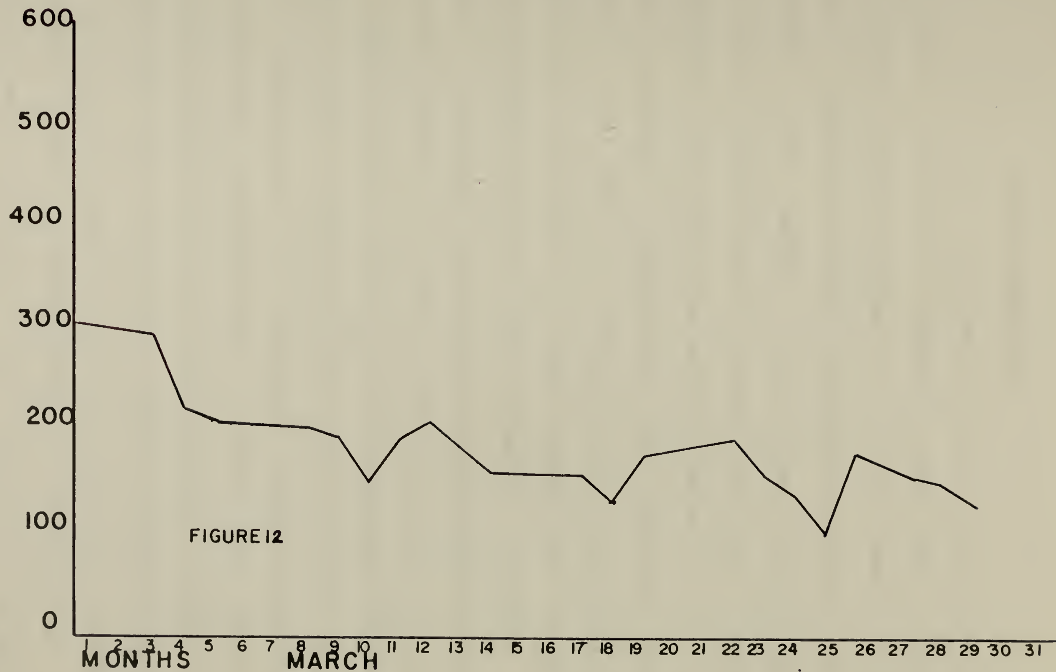


FIGURE 12

missed. The several peaks and depressions in this graph represent composite item clearance "pushes" followed by pre-criticality inspections which generate additional work items (days 9, 18, and 24).

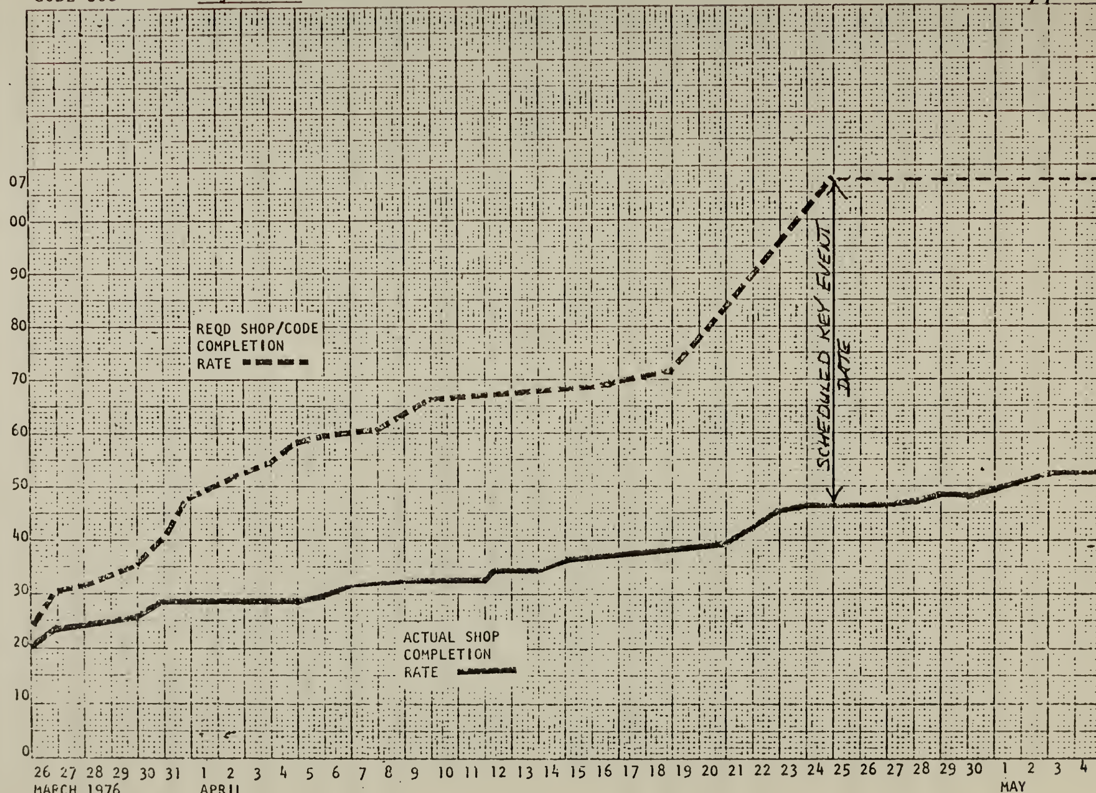
b. Test Progress Summaries

As the dock trial and criticality key events approach, dockside tests on the affected systems must be completed and the results reviewed in an orderly fashion to allow time for necessary rework. For these key events, Code 365 prepares a daily summary of test documents outstanding for the ship by action code (not shown) and a plot of required test completion rate versus the actual completion rate (figure 13). Such a summary is prepared for tests under the overall cognizance of Code 290 (Hull, Propulsion, and Auxiliary Systems Test Group) and Code 190 (Combat Systems Test Group). The test documents listed on these summaries are those "starred" by the Chief Test Engineer representing the above codes for the particular overhaul during his pre-event review of the source documents listed in the Non-Nuclear Composite. "Starring" is used to indicate that a given item must be completed for the key event of concern and is used to update the initial key event assignment made by Code 365 when the document was entered into the Non-Nuclear Composite System. Starring thus takes into consideration special circumstances which may have arisen which render the initial key event assignment inappropriate. Once the starring process is completed, the non-nuclear composite becomes a valid legal source of work and

CODE 365

Figure 13. SSN 613 DOCK TRIAL TEST PROGRESS (290 PORTION)

ISSUE DATE: 5/4



tests remaining to be accomplished before the key event can commence.

The information contained in the test progress summaries can be used to assess whether the test document clearance rate achieved by a given code/shop is sufficient to support the key event as scheduled. If not, resource reallocations may be possible to restore the required clearance rates. As the reader may surmise, in the case demonstrated by figure 13, the key event, scheduled for 25 April, was missed because the actual testing progress lagged the required rate too greatly to be made up simply by the addition of additional testing manpower. In cases like this, limited working space resulting in physical interference aboard the submarine often precludes the Repair Officer from taking what appears to be the obvious course of action.

c. Ship Superintendent Ad Hoc Management Aids

Depending upon the phase of the overhaul, the Repair Officer requires the ship superintendent to develop their own means of keeping track of general progress. Typical examples include lists of equipment removed (ripped-out) from the ship, completed weld joint listings, lists of equipment such as pumps, motors, and valves in the various shops by priority for completion, or, since the scope of certain repairs are not known until the component is inspected, lists of critical inspection reports, both required and completed. Although the Repair Officer may personally view these lists, more typically he relies on summary information presented to

him by the ship superintendent as a means of assessing progress in these areas.

d. Prerequisite Lists (PRL's)

As previously discussed in Chapter III, formal prerequisite lists (PRL's) are prepared by the shipyard for "high risk" evolutions in compliance with Reference 9 and thus form an exception to the remarks with which the author opened the discussion of locally generated forms in that they are not optional at the local level. High risk evolutions include docking, steaming, dock trials, undocking, and others. PRL's may be prepared for other key events as well, however. PRL's are prepared by the HP&A Test Engineering Branch, Code 290.8, and are concurred in by the ship's Commanding Officer and other affected shipyard codes. The PRL includes signoff spaces for verification that each prerequisite condition has been met and a description of the required state of readiness for each system. It also includes the list of "starred" test documents included in the non-nuclear composite which must be completed prior to the key event. The requirements of each PRL are based upon the latest NAVSEA requirements plus any additional items considered prudent by the shipyard or ship's company.

Although officially maintained by the HP&A Test Organization (Code 290), the PRL is provided to the Repair Officer and others to assist in managing the non-nuclear production preparations for the key event. The PRL thus is another tool which the Repair Officer uses to focus the

attention of ship superintendents and shop supervisory personnel on specific items to be completed. By its signature verification feature, it also gives the Repair Officer assurance that items signed off (on the official copy) have actually been completed and that readiness for the event is complete.

e. Marked-up System Schematics

As the Engine Room steaming key event approaches, several control problems confront the Repair Officer. Typically, the lube oil systems prove controlling for this event since they must be fully operational including flushing and hydrostatic testing. Because these systems and others, such as condensate, may be worked under a single work permit, monitoring progress using the non-nuclear composite would not yield sufficient information on the day-to-day status changes since nothing would be reflected in the composite reports until all work was completed. In cases such as this, the Repair Officer makes use of marked-up system schematics maintained by Code 365 which show portions of the systems not intact, portions under test, portions flushed, and portions hydroed. These marked-up schematics (based upon information provided Code 365 by the Production Shops) enable the Repair Officer to assess the rate of progress on critical lube oil, condensate, and other systems as the overhaul progresses.

f. Weekly Manning Projection vs.
Actual Expenditure Report

Complementing the information presented in the Daily Force Distribution Report (PF-102B) discussed earlier

is the Weekly Manning Projection versus Actual Expenditures Report (figure 14). Prepared and distributed weekly by the Work Status Section (Code 376), this report presents manning data by shop (left hand margin) by ship, comparing the forecast amount of mandays against what was actually expended in both the nuclear and non-nuclear areas. A net variance for each ship is shown at the bottom of the page and a net variance by shop at the extreme right hand column (not shown). Knowing the priorities of the various ships, the Repair Officer looks for positive variances (overmanning) on low priority units and negative variances (undermanning) on high priority units. The combination of these two circumstances may indicate a need for personnel reallocation unless some reason (physical interference, for example) is known for the apparent misdistribution. Similarly, by interpreting the shop variances, the Repair Officer can spot bottlenecks and excess capacity and may be able to reschedule work to take advantage of this knowledge.

As an example, by looking at figure 14, the Repair Officer, knowing that WASHINGTON is a high priority ship and that SAILFISH (SS 572) is low priority (priorities assumed for purposes of illustration) may note that the latter is 108 mandays overmanned whereas WASHINGTON is undermanned by 236 mandays for the week. Further inspection reveals that shop 11 (shipfitters) was considerably undermanned on WASHINGTON yet overmanned on SAILFISH. This type of item would prompt a call to the shop head suggesting that priorities be reviewed.

SWLF = Shop Workload Forecast
ACT = Actual Average
NN = Non-Nuclear
N = Nuclear
NN/N

PRODUCTION DEPARTMENT

Figure 14. WEEKLY MANNING PROJECTION VS ACTUAL EXPENDITURE

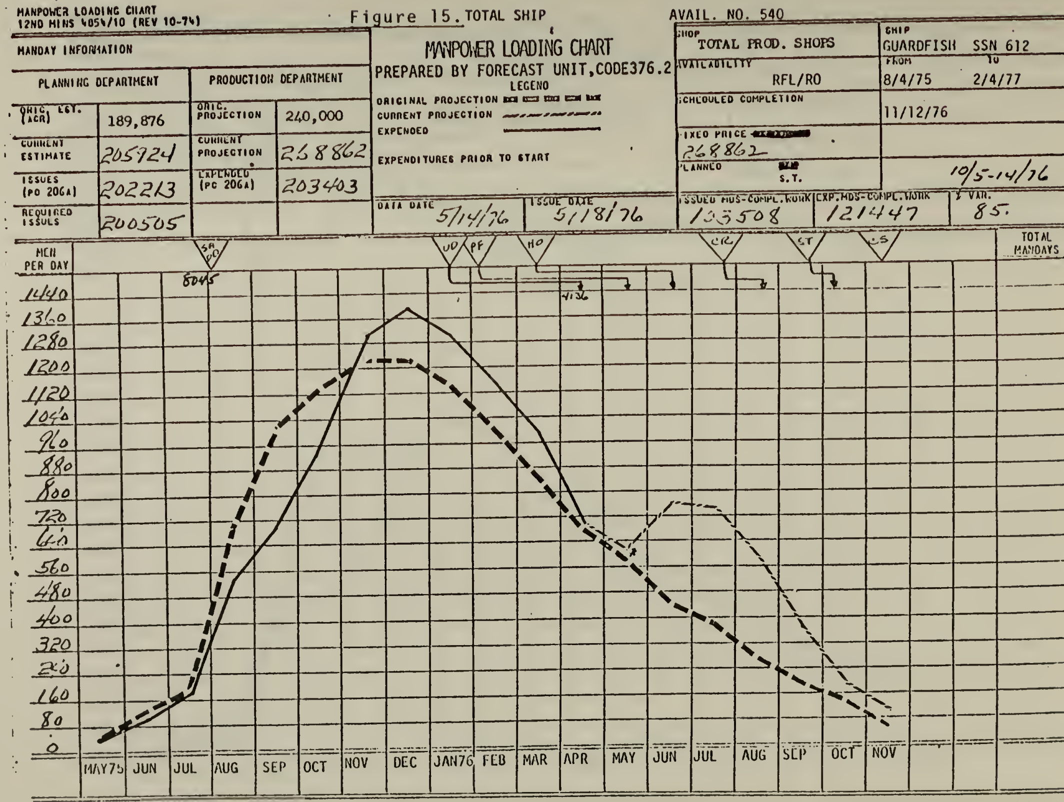
Actual Average 4/3/76 - 4/9/76 Projected for week of 4/5/76

		MARSHALL SSBN 611		FLASHER SSN 613		GUARDFISH SSN 612		WASHINGTON SSBN 598		STM GEN CL SSBN 598		HALIBUT IA SSN 587		P. HENRY SSBN 599		SAILFISH SS 572		BARBEL SS 580	
		SWLF	ACT	SWLF	ACT	SWLF	ACT	SWLF	ACT	SWLF	ACT	SWLF	ACT	SWLF	ACT	SWLF	ACT	SWLF	ACT
920	11	4/-	4/-	18/3	23/1	52/11	46/3	64/21	43/11	-/8	-/12	8/4	6/1	1/7	13/4	11	26	12	12
	17	14	6	28	25	39	21	42	23	1	8	6	-	2	3	16	30	13	10
	26	4	7	14	18	72	60	91	45	5	14	8	4	7	7	8	18	10	9
	41	-	1	1	2	10	8	21	13	-	2	-	-	1	1	1	1	4	3
	55	10/-	11/1	48/12	44/21	159/26	103/52	77/53	73/41	-/54	-/26	4/10	1/26	1/9	-/7	36	93	49	41
930	05	-	-	1		6	9	8	10	-	2	4	3	2	-	1	-	1	-
	23	-	-	-		2	2	4	2	-	-	1	-	-	-	-	1	1	1
	31	5/-	2/-	10/2	14/1	16/6	26/2	129/20	96/30	-/2	-/10	1/1	-/2	1/5	4/2	16	7	16	16
	33	23/1	43/1	55/5	97/5	101/30	87/35	83/74	55/82	-/-	-/2	7/12	-/15	-/2	-/2	43	60	59	46
950	36	3/-	16/-	6/-	19/1	10/1	10/-	90/1	69/5	-/-	-/-	-/-	-/-	-/-	-/-	3	2	8	13
	51	12/-	16/-	31/9	60/15	86/27	71/15	105/57	108/43	-/-	-/-	3/2	-/1	1/1	-/2	35	44	26	13
	67	7/-	19/-	17/2	19/9	11/7	9/11	14/7	6/43	-/-	-/1	1/-	-/-	-/-	-/-	8	7	8	9
970	64	4	3	20	18	46	49	42	21	2	1	7	5	2	-	9	7	8	6
	71	12	13	34	37	17	34	52	36	1	1	3	2	1	-	5	4	6	7
	72	6	16	21	29	93	106	122	104	2	-	35	19	3	1	10	10	17	21
	99	2	4	11	9	41	24	37	19	4	2	10	16	2	-	7	7	6	11
		106	156	348	458	869	732	1214	978	79	81	127	101	48	46	209	317	244	218
			+50		+110		-87		-236		+2		-26		-2		+108		-26

g. Manpower Loading Charts

Prepared approximately quarterly by the Work Status Section (Code 376), the Manpower Loading Chart provides a visual summary of the information contained in the Daily Force Distribution Report (PF 102B) and Weekly Manning Projection versus Expenditure Reports (see figures 15 and 16). Four different presentations are prepared, one for each of the availability types (nuclear, non-nuclear, refueling) and one for the total ship. Within each presentation type, data is presented for all shops (figure 15) and for individual shops (figure 16). The information presented is the Code 376 forecasted manday expenditure profile for the availability (dotted line) and the actual manday expenditure profile to date. Key event flags are presented across the top of the graph for easy reference with official reschedulings indicated by arrows from the flag. The forecasted profile is normally developed when the work package is firmed and the short-range manday estimates previously discussed are developed. The forecasted profile thus represents, based upon historical manning profiles for similar availabilities and inputs from the production shops, the shipyard's best estimate of how the total short-range manday estimate must be distributed to achieve the shipyard's internal schedule for the overhaul. The reader will recall that the short-range manday estimate includes an allowance for growth within scope and an allowance for previous shop performance in meeting the planner's manday estimate.

Figure 15. TOTAL SHIP



MANPOWER LOADING CHART
12ND MINS 4054/10 (REV 10-74)

Figure 16. TOTAL SHIP

AVAIL. NO. 540

MANDAY INFORMATION			
PLANNING DEPARTMENT		PRODUCTION DEPARTMENT	
ORIG. EST. (ACR)	25,553	ORIG. PROJECTION	40,029
CURRENT ESTIMATE	29068	CURRENT PROJECTION	38585
ISSUES (PO 206A)	28536	EXPENDED (PO 206A)	30879
REQUIRED ISSUES			

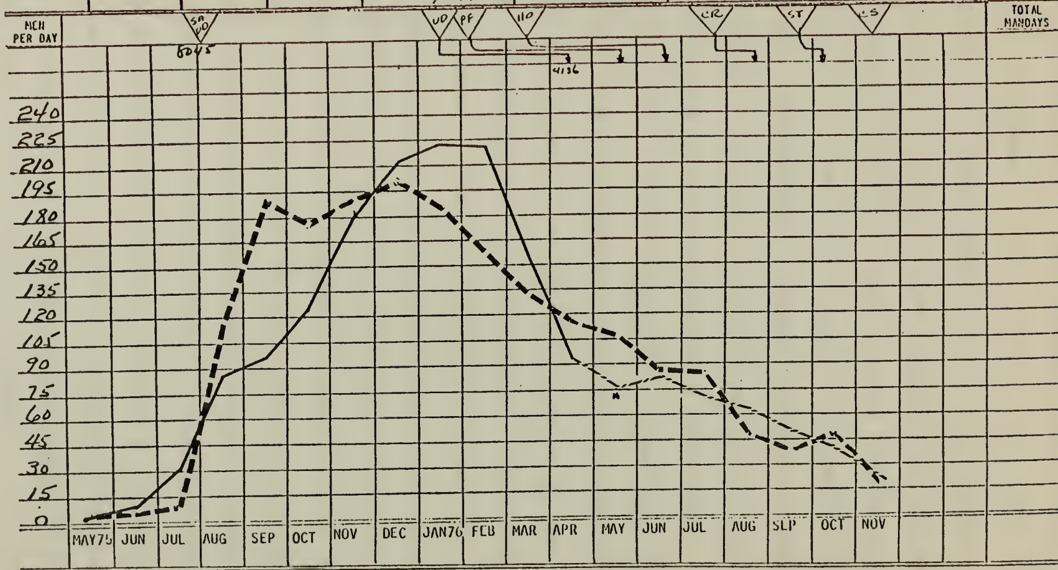
MANPOWER LOADING CHART
PREPARED BY FORECAST UNIT, CODE376.2

LEGEND
ORIGINAL PROJECTION
CURRENT PROJECTION
EXPENDED

EXPENDITURES PRIOR TO START

SHOP	SHIP
38	GUARDFISH SSN 612
AVAILABILITY	FROM / TO
RFL/RO	8/4/75 2/4/77
SCHEDULED COMPLETION	11/12/76
FIXED PRICE [redacted] 38585	
PLANNED S.T.	10/5-14/76

DATA DATE	ISSUE DATE	ISSUED MDS-COMPL. WORK	EXP. MDS-COMPL. WORK	% VAR.
5/14/76	5/18/76	15890	20143	79.



The author examined several of these manpower loading charts in the course of the research and quickly came to appreciate the power of this display as a tool for forecasting problems in an availability. It was apparent, after reviewing these past charts, that significant departures from the forecasted profile early in the availability, due either to lack of shop personnel, priority conflicts, or whatever, were almost impossible to makeup in time to meet the original schedule. Physical interference in the confined submarine quarters plays a significant role here. Thus, undermanning early in the availability, particularly prior to undocking, usually presages slips in all downstream key events. Further, delaying undocking on one ship can adversely affect the overhaul of the follow-on vessel due to limited drydock space. Thus, the Repair Officer is very concerned with these manning profiles and endeavors, within the limitations of workers available, allowable overtime, and subcontracting to keep the manning as close to the forecast as possible. The complexity of this task is overwhelming, however, when the interacting demands seven or eight ships simultaneously on the available manpower pool are considered. In the most critical trades, shops 38, 51, and 56, a slippage of a major key event, such as undocking on one ship, immediately perturbs the manning expenditures on all other ships. The balance is extremely tenuous.

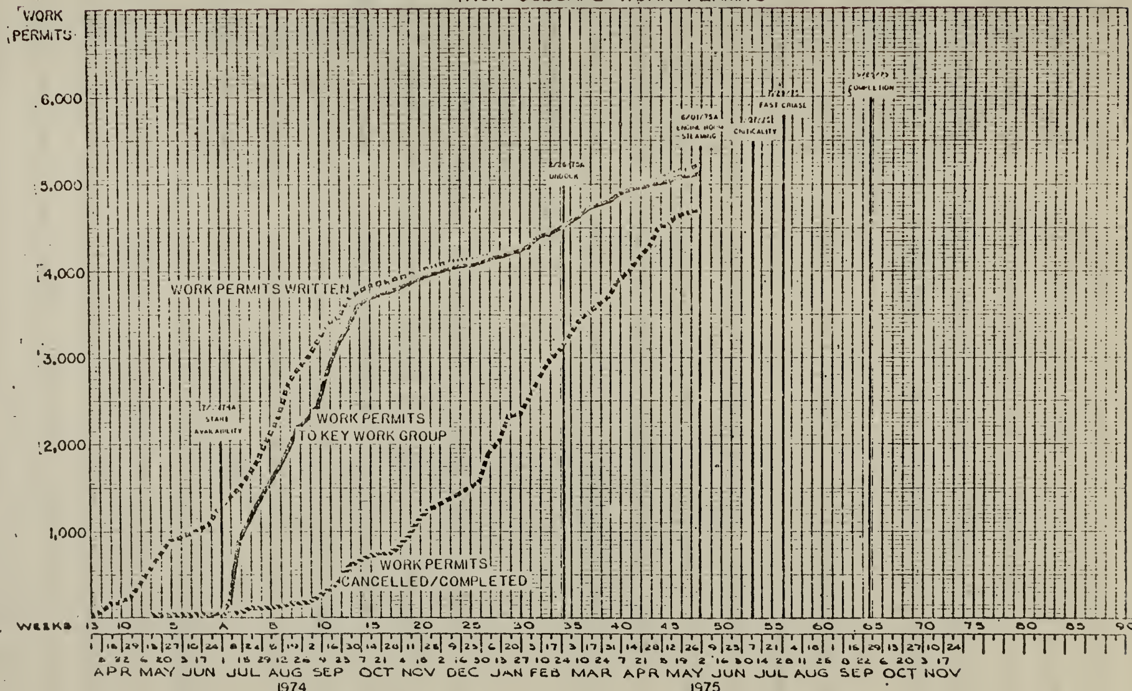
As an example of how figures 15 and 16 might be read, consider figure 15. It is apparent that from the point

of ship arrival and drydocking (first "flag" at top of chart), total shop manning fell considerably behind the projected requirements, probably due to conditions on other ships (a similar conclusion emerges from figure 16 for shop 38 manning). As a result, when manning did become available for this ship (early November) a big manning "push" resulted. As stated above, however, manning lost early is difficult to make up. As a result, the undocking (UD) key event is shown to have slipped three months, with other key events also slipping. Present in this case, and in many others the author examined, was the close correlation of the total area under the actual manning profile to the area under the forecast manning profile through the undocking point. This attests to the accuracy of workload (and thus manpower) forecasting for this overhaul segment.

h. Work Permit Plots

Because work permits (also known as "Ripouts" or "Re-entries") constitute the basic record used to document and control non-nuclear work on submarine systems, their generation, distribution to cognizant shops, and clearance basically constitute the other side of the manning picture in that rates of progress in these areas reflect <u>work actually done</u>. Accordingly, Code 365 maintains plots of these three progress measures versus time for each ship starting several months prior to arrival (figure 17). The Repair Officer's interest in these plots focuses prior to the ship's arrival (Point "A" on figure 17) on insuring that work permit

FIGURE 17. T. JEFFERSON (SSBN 618)
NON-SUBSAFE WORK PERMITS



generation is rapid enough to fully support all work required at the arrival date. He also monitors to insure that a large gap does not develop between work permits written and issued to the shops and finally to insure that plateaus or decreasing slopes do not develop in the rate of clearance. Any of these conditions indicate to the Repair Officer that despite manning levels, work progress is not adequate and further investigation is required.

As an example, in figure 17 it is apparent that shortly after ship arrival a large gap did remain between work permits written and those issued to the cognizant ships. Further, although not apparent from this figure, by experience the Repair Officer observes early that the work permit clearance rate is insufficient to meet the original undocking date of 11 January 1975.

i. Schedules

The Repair Officer has available listings of the internal schedule key event dates for use in the production management process. These listings take the place of the bulky PERT networks for ease in reference. The Repair Officer has access, however, to the detailed networks by system described in Chapter IV if he needs them.

In addition to the detailed networks prepared for the job scoping conference and referred to above, a 21 Day Schedule (network) is prepared by Code 377 (Scheduling Section) for the three weeks commencing upon ship arrival. This schedule reflects the shipyard's detailed plan for the

first three weeks of the availability, during which time the ship is docked and major ripout of equipment and hookup of temporary services commences. It is used by the Repair Officer as a standard of overall performance monitoring early in the availability. Such detailed shift-by-shift management of this early overhaul activity insures that bottlenecks and supervisory problems which, if left uncorrected, could jeopardize the entire schedule are identified and corrected at the earliest possible time. It also insures that the very busy first three weeks proceed with a maximum of coordination.

4. Verbal Reports and Feedback Devices

a. Briefings by Ship Superintendents

Early each morning, except on weekends, the Repair Officer is briefed by each ship superintendent on emergent bottlenecks and general work progress since the previous briefings. This briefing enables the Repair Officer, at his morning meeting with the Production Officer and group superintendents, to bring up the trouble areas for resolution. These morning briefings are supplemented by further reports as necessary during the working day and after hours to keep the Repair Officer fully advised of problem areas causing work stoppage or slowdown. Elimination of such bottlenecks is an important facet of the production management process and will be discussed in further detail in Chapter VI.

b. Weekly Work Progress Conference

Weekly throughout the overhaul the Repair Officer holds work progress meetings with the Ship Superintendent

and leading shop personnel to discuss the status of work accomplishment. Just as the production management aids used vary with the phase of the overhaul, so do the content of these conferences. The basic purpose for such a meeting remains constant, however, and that is to discuss job status in the presence of those responsible and to gain commitments, where appropriate, for the completion of lagging work. The Repair Officer stated "...if a supervisor has not done his job he will be a little uncomfortable in these meetings..." Imbuing a feeling of responsibility for work progress in key supervisors is thus an important purpose of these conferences.

A typical conference agenda includes a review of the Non-Nuclear Composite gross numbers by shop for the next key event, a review of testing status, and a review of coming minor events in the production sequence. Special problems which the shops are having are identified and planned corrective action is sought from the responsible supervisors.

As a major key event approaches or as a major job gets behind schedule, these meetings become more detailed in scope and more than one such meeting per week may be held. During such meetings, the Repair Officer requires the ship superintendent to prepare and present a detailed short-range schedule, typically of the GANTT type, showing the completion-of-work sequence. This document is then used to gain commitments from the supervisors regarding completion of the scheduled steps. Such a short-range schedule, in addition to providing accountability, also serves to get all

supervisors moving in the same direction and provides an excellent document for supervisor and ship superintendent shift turnover.

Also, in preparation for upcoming key events, the PCL 217E detailed listing of outstanding composite items previously discussed becomes part of the meeting agenda. Again the emphasis is on gaining commitments from supervisors and identifying problem areas for early resolution.

Because of the significance of the undocking event, the Repair Officer also uses a special agenda for meetings preceding that event. This undocking agenda is basically a tickler listing of items which have controlled undocking in the past to make sure they are being properly pursued. Thus, the Repair Officer may seek details on tank closure status, rudder and stern plane progress, and other items not specifically addressed elsewhere in a readiness-for-undocking context.

c. Weekly Meeting with the Ship Commanding Officer

Weekly, after the work progress conference, the Repair Officer meets with the Commanding Officers of the overhauling ships to present to them the status of the overhaul. While the information presented to the Commanding Officer is largely based upon data accumulated in the work progress conference, the Repair Officer receives from the Commanding Officer his comments regarding the overhaul--a sometimes valuable input since the Commanding Officer can point out problems the ship's company may be having either

with their own work (upon which the completion of some shipyard work may depend) or in supporting shipyard work. In addition the Commanding Officer may point out areas of unsatisfactory work or work progress which require further evaluation and action by the shipyard.

F. SUMMARY OF PRODUCTION MONITORING AIDS

The reader by this point undoubtedly has an appreciation not only for the variety of management tools available to the Repair Officer, but also for the varieties of circumstances under which different tools are used. Figure 18 presents a brief summary of this chapter by classifying the various management aids as to their usage, either as (1) routine production monitoring devices or (2) special aids used to insure total readiness for a key event or (3) aids used to monitor a particularly important or behind-schedule work item.

ROUTINE MANAGEMENT AIDS	KEY EVENT READINESS MONITORING AIDS	SPECIAL OR BEHIND-SCHEDULE WORK ITEM MANAGEMENT AIDS
Daily Force Distribution Report	PCL 217E Tape	PCL 217G Tape
Weekly Manning Forecast vs. Actual Expenditure Report	Plot of Total Composite Items	Short Range Schedules
PCL 216B Report	Test Progress Summaries	Special Work Progress Meetings
Ship Superintendent Ad Hoc Manangement Aids	Prerequisite Lists	
Marked up System Schematics	Short Range Schedules	
Manpower Loading Charts	Special Agendas (undocking)	
Work Permit Plots		
Briefings By Ship Superintendent		
Weekly Work Progress Conferences		
Weekly Meeting with Commanding Officers		

Figure 18. Summary of Production Monitoring Aids

VI. SEEKING SCHEDULE ADHERENCE ---THE TRADEOFF PROBLEM

A. PURPOSE

In reality, the Repair Officer's problem is:

GIVEN SCHEDULE, WORKLOAD, AVAILABLE MANPOWER, AND COST CONSTRAINTS, HOW CAN SCHEDULE ADHERENCE BE ACHIEVED SIMULTANEOUSLY ON SEVERAL SHIPS IN AN OVERHAUL ENVIRONMENT? As the title implies, this process is rarely executed without some tradeoffs and, in practice, seeking schedule adherence on one ship may, at least in the short run, cause a schedule departure on one or more other ships. Similarly, even if a schedule-maintaining course of action can be taken on one ship without affecting others, such a course of action may be costly. The author does not attempt to examine the full realm of schedule adherence problems typically encountered in management of a nuclear submarine overhaul in this chapter; such a task could fill many volumes and still leave the reader unsatisfied. This is because each such problem is slightly different and a fine degree of managerial judgement is required. This chapter will thus seek to define the techniques employed at Mare Island to achieve schedule adherence, to examine the considerations involved, and finally to suggest to the reader the true complexity of the schedule adherence problem.

B. BASIC PROCESS PARAMETERS

As Chapter IV explained, there are four basic parameters involved in the production management or schedule adherence process on a single ship: schedule, available workforce, authorized workload, and estimated cost. The author assumes in this chapter that initial values for each of these parameters have been developed as described in Chapter IV for each of several overhauling vessels. As was stated earlier, since workforce augmentations are not possible in the short run, the shipyard labor base is assumed fixed throughout this chapter. The reader will recall that this workforce is currently insufficient to meet the projected workload without the use of overtime and subcontracting. These points will be amplified upon below. Further, because the day-to-day decisions involved in the production management process are primarily geared to achieve schedule adherence, an analysis of the cost impact of the various courses of action considered will be discussed as consequence of those courses of action rather than as a variable which is consciously manipulated. The reader should thus realize at the start that in the discussions which follow the goal of these courses of action is to accomplish the authorized workload within the internally scheduled dates using the available manpower resources.

C. GENERAL CONSIDERATIONS

1. Cost-Schedule Relationships

The reason the author elected to treat costs as a consequence of day-to-day production management decisions

rather than as a driving consideration in their formulation is the Mare Island philosophy that, in striving to achieve the schedule, a near-optimum degree of control over customer-borne real and opportunity costs is simultaneously achieved. The components of this philosophy are threefold.

First, meeting (or bettering) the scheduled overhaul length generally means that an adequate level of skill exists in the shipyard shops so that time (and cost) consuming re-work is minimized.[4] Further, if, as in the case of Mare Island, a low skilled-to-unskilled worker ratio exists, achieving schedule adherence implies that supervision leading to the rapid identification and correction of deficient work has been intense, thus minimizing the effects of the low skill level condition. In this case, while the material and labor cost increase of the rework cannot be averted, some of the unplanned costs due to schedule slippage are (see below).

Secondly, the customer receives specific cost benefits from on-time or early ship completion. These benefits result not only from the opportunity costs saved when the submarine is returned to service but also in the use of lower stabilized manday rates on future hulls because the ship was not consuming resources beyond her projected overhaul duration. (The

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[4]The magnitude of the rework problem varies considerably depending on the type of work involved. As might be suspected, welding, where defects are usually not known until after non-destructive tests (such as x-ray inspection) are completed, the rework rate is quite high, perhaps 20 to 30 percent. On valves, where the work involved normally includes a complete overhaul to stop leakage both into the ship and past the seat, rework rates due to all causes are about ten percent. For larger jobs, such as pump and motor overhauls, the rework rate is generally lower, perhaps 2 to 3 percent.

reader will recall that the shipyard must price work so as to break even in the long run.) The unfavorable fixed price variance resulting from a ship whose schedule is not met is thus ultimately borne by the customer through price increases on subsequent vessels. The customer further benefits from early or on-schedule ship completion by the avoidance of bottlenecks on other ships in overhaul due to unplanned resource expenditures on the ship in question. The cost of these bottlenecks, as they affect schedule adherence on these other vessels, are ultimately borne by the customer as described above. By eliminating such bottlenecks, the overall productive efficiency of the shipyard is enhanced and future costs to the customer can be reduced.

Finally, meeting or bettering the scheduled overhaul completion date, particularly in the case of Mare Island where the inherent labor base is below the projected requirements, implies that managerial employment of the various hedges discussed below against this disadvantage has been effective. These hedges each contain cost-saving features when properly employed.

The author notes one unstated yet basic assumption in this philosophy: pursuit of the schedule must be efficient. This means, for example, that any inefficiency in performance (such as funding several alternative and parallel courses of action to solve a production problem) however well-intended, will cause a departure from the "minimum cost" concept. In this instance, the author intends "courses of action" to mean

different approaches to accomplishing a given task rather than tasks which would of necessity be done anyway. Thus, once one of these courses of action is successful, any money or time spent in pursuit of the others is lost.

2. Determination of Project and Job Priorities

Inherent in the discussion which follows is an assumed knowledge by the Repair Officer of project (ship) and job priorities. Although the guidance of reference 10 gives SSBN type ships precedence in an even tradeoff situation, the problem is rarely that simple. Even though a given ship may have overall priority because of the nearness of a major key event, some jobs on lower priority ships may be just as important or more important than some work on that ship.

To help clarify the question of priorities, the morning meeting of the Repair Officer, Production Officer, and group superintendents is attended by the Shipyard Commander. At this meeting, problem areas and bottlenecks are discussed and, if necessary and with the approval of the Shipyard Commander, priorities are assigned. Generally, ship priorities are not specifically discussed but follow a general rule: the closest ship to completion has the highest priority with nuclear ships ranking above non-nuclear. Job priorities, where not discussed at the morning meeting, are determined by the Repair Officer and group superintendents by experience and their knowlege of the pending key events on the various ships. Thus, even though no problems are being encountered, completion of a hydrostatic test of a system on ship X (sixth

in ship priority) to support operational testing of the system scheduled for the following day is pursued as an important job.

Priority guidance resulting from the morning meeting with the Production Officer and Shipyard Commander is carried to the shop heads by the group superintendents in a separate meeting which immediately follows. Similarly, shifts in priority are conveyed to ship superintendents by the Repair Officer.

Since shift turnovers to the evening and graveyard shift are a possible source of communications breakdowns regarding jobs to be worked, the Repair Officer, assisted in the drafting and preparation by the ship superintendents and shop heads, issues a daily teletype to all trades advising them of the priority work by ship to be pursued during the 24-hour period commencing with the evening (swing) shift. Trade responsibility and points of contact for notification of impediments to progress on the listed jobs are also assigned in this teletype message.

3. Manning Limits and Constraints

Chapter V introduced some of the complexities involved in the determination of ship manning. Central to any decision to manipulate the manning on a given ship in a given area are two primary considerations.

The first effect to be considered is the number of people already working in the area. Even though a job may be seriously behind schedule, work may be proceeding on the job

(or on other jobs in the vicinity) such that the area is physically saturated with workers---adding more workers might even be counterproductive in such an instance. The shipyard has conducted loading studies which give rough bounds on the limits of men for the various critical work areas. This factor can play an important part in determining the appropriate course of action.

The second factor which must be considered is the impact of the contemplated adjustment on other vessels. Scheduled key event date slips to accommodate a single trade in trouble, for example, can have a snowballing effect by providing slack to other critical trades, causing the latter to remain on the ship working when they should have been completed and moving to the next ship. Similarly, pulling too many workers from a job on a ship where some slack exists may eventually cause that job to fall into the critical path to overhaul completion.

Because these two effects are complicated many fold by a multi-ship environment, the Repair Officer does not personally decide upon day-to-day numbers of the various tradeworkers assigned to the non-nuclear production task. Rather, he provides guidance to the shop heads as to jobs which deserve more or less attention and relies upon the shop head to efficiently assign his men. The Repair Officer then uses the various tools described in Chapter V to monitor the <u>results</u>, for example, an increasing rate in the clearance of composite items. If the results are still inadequate, the Repair Officer again speaks to the shop head.

By employing this method of dealing with the manning problem, the Repair Officer avoids becoming a bottleneck himself and builds a strong sense of responsibility into the shop heads for their actions. It also places this critical decision-making responsibility at the level most aware of the long-term implications involved in carrying it out.

4. Bottleneck Resolution

Occasionally, despite the assignment of job and ship priorities, a shop head is confronted with a situation calling for more resources than he has. Typical are simultaneous manning requirements for multiple priority jobs on several different ships, both nuclear and non-nuclear requirements for the same piece of equipment, and others.[5] These situations, until resolved, become a bottleneck slowing or stopping progress on critical work. When such bottlenecks cannot be resolved by the ship superintendents involved (usually by one yielding to the other), the Repair Officer is called in to provide guidance.

Again, without telling the shop head how to distribute his resources, the Repair Officer provides the necessary clarification of priorities and advises the ship superintendents of the guidance provided. In the case of a nuclear/non-nuclear issue, the Repair Officer and Nuclear Repair Officer jointly reach a compromise. In very unusual circumstances, the Production Officer or even the Shipyard Commander may be called into the resolution process.

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[5]It is not unusual for a shop to be actively pursuing a hundred jobs a day on a single ship.

D. SCHEDULE ADHERENCE OPTIONS

Each of the techniques to be discussed below represents a choice available in the multi-ship schedule adherence process. Because schedule adherence problems reside in the fact that the authorized work is not being done rapidly enough, three of these techniques are also used routinely as a hedge against the inadequate labor force discussed previously.

1. The Use of Overtime

Proper use of overtime can have a very positive effect on the schedule adherence of a vessel. On the other hand, fully understanding the mechanics, economics, and considerations involved in overtime management is an elusive task. For example, the reader may feel, as the author mistakenly did early in the research, that given the use of overtime, schedule adherence is always possible if one is willing to accept the added costs. This impression is incorrect.

First, as stated in earlier chapters, NAVSEA has imposed a limit on the use of overtime on all naval shipyards. For Mare Island, this limit is an average of six percent of the total labor force per quarter. Depending on the labor force on board, this limit translates to about 3000 to 3200 mandays per week of overtime available. However, this amount is the combined total for nuclear repairs, non-nuclear repairs including supply, public works, and indirect labor. During any given week, as little as 1100 mandays may actually be available to augment the regular direct shift work in the non-nuclear area. This amount, even when supplemented by a

small amount of nuclear repair overtime, is insufficient to offset the average projected labor shortage of about 650 mandays per day [Ref. 3]. Other techniques must be used to close this gap (see below).

Similarly, the economics of overtime usage are not what they at first appear to be. In fact, for several reasons, overtime usage is a cost-saving technique to the customer despite the fact that overtime wages are 50 percent greater. The anomaly may be understood if the reader considers the basic relationship between mandays required for a job and time to complete the job. In the absence of work area saturation effects (which overtime can help to reduce), doubling the manpower halves the time or, alternatively, not using continuous manning by holding back on overtime extends the time. Looking at a total ship, it then follows that continuing manning on critical path jobs through the weekends (overtime) should reduce the overhaul schedule length. The implied economics to the customer of shorter duration overhauls discussed earlier pertain here as well.

There is another more subtle economy to be realized in overtime usage, however. The customer is charged the same stabilized manday rate throughout the overhaul, regardless of whether the manday is overtime or not. However, offsetting the larger than normal portion of this manday charge consumed by the higher worker wage rate are smaller charges during overtime periods for indirect or supervisory workers. This is because fewer supervisors and other indirect workers are

onboard during overtime periods. Thus, the declining indirect to direct labor ratio during overtime periods leads to further economies.[6]

Finally, because certain major items of physical equipment, such as cranes, are used during overtime periods, these assets are not idle expenses during such times, absorbing a portion of the overhead costs but producing nothing. This factor, too, serves to favor the use of overtime.

The reader may wonder why an overtime limitation is imposed at all. The author believes there are two primary reasons. The first is the tendency for overtime to be abused by shop personnel if not carefully controlled. The second is a full-employment consideration. With national unemployment in excess of seven percent, reducing authorized overtime tends to force fuller employment than would be the case if unrestricted overtime were permitted.

The six percent per quarter limit on the use of overtime is of some help in easing the existing deficits in the available work force. However, until late 1976 when the projected deficit drops to about 400 mandays per day, the overtime limit alone is still insufficient to bridge the gap. Further, the necessity to use overtime labor for this purpose tends to reduce the flexibility which would otherwise exist in applying overtime to critical path work. In practice, the

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[6]While the total <u>number</u> of supervisors declines during overtime periods, the <u>decline</u> in numbers of direct workers is even greater so that the supervisor to laborer ratio actually becomes more favorable during these periods. This remains true even through the overall ratio of indirect labor (which includes a large number of non-supervisory personnel) to direct labor declines, as stated.

most urgent jobs in relation to pending key events are manned through the weekends while other important critical path work simply is not in some instances. The negative influence of a deficient workforce can, of course, be offset by other means (see below). To the extent that these are successful, managerial flexibility in applying overtime to strictly critical path work is restored.

The overtime allocation and approval process in the non-nuclear production area is conducted on a weekly basis. Each other overtime user (public works, nuclear repair, and production indirect labor) prepares and submits overtime man-day requirements for the coming weekend (Saturday day shift through Sunday graveyard shift) and the following working week to the Repair Officer who absorbs the remainder so as to bring the weekly shipyard total within the six percent limit. In practice, he may submit a total requirement figure slightly in excess of the six percent limit in anticipation of a small number of "no show" workers.

The shop heads and ship superintendents advise the Repair Officer each Thursday of work items by ship for which overtime authorization is requested in order of priority. The Repair Officer then assesses the available amount of non-nuclear overtime, the requested list of work items, the project and job priorities, and the general trade postures on the ships in question and allocates overtime up to the allowed limit. In this process, the Repair Officer may determine that a legitimate need exists in the non-nuclear area for additional

overtime for the week in question. Unless the amount is small, some other user's requirements must be reduced in such a case. This situation is resolved when the entire overtime requirements package is subsequently reviewed by the Production Officer and finally reviewed and approved by the Shipyard Commander.

The detailed preparation, review, and approval process described above provides a fine degree of control over overtime usage. Subsequent modifications to the approved package in the non-nuclear area, due to oversight or unexpected changes in work status, are personally approved by the Repair Officer.

To give the reader an appreciation for the approximate size of the overtime work force on a given ship, a typical non-nuclear weekly overtime allocation of 1200 mandays will be examined. Since this is normally expended primarily on the six weekend shifts, there are about 200 mandays per shift available. With ten ships in the yard undergoing various types of work, this means, on the average, 20 men per shift per ship. While in practice, some ships receive more than this average figure and others less depending on priorities, the numbers involved are nevertheless small in comparison with the normal direct labor application per shift during the work week, which is in excess of 300 men on the average.

2. <u>The Use of Subcontracting</u>

Subcontracting work to private concerns represents another important technique useful in offsetting the effects of the deficient work force and also in maintaining schedule adherence.

NAVSEA, in reference 15, prescribes limits on the subcontracting of shipboard work. Specific NAVSEA (07) permission is required, for example, prior to permitting contractor personnel aboard the submarine. However, no restrictions are placed upon the unshipping of components for work at a contractor's plant. Further, many major shipboard components are amenable to this treatment and a degree of flexibility lost in the use of overtime can thus be restored.

Prior to the start of an overhaul, conscious decisions regarding what components will be subcontracted are made. The driving consideration in these decisions is the projected trade requirements and availability for the ship in question when the effects of interaction with other ships and the size of the work package are considered. Table 1 shows a listing of subcontracted work during a recent SSBN overhaul.

Table I. SUBCONTRACTED WORK DURING RECENT SSBN OVERHAUL

Overhaul 34 High Pressure Air valves
Rewind 2 300 KW motor generator sets
Conduct Miscellaneous sandblasting of hull and tanks
Install new quills, pinions, and reduction gear hubs
Overhaul 174 missile air valves
Manufacture reduction gear couplings and sleeves
Overhaul 7 steam distilling plant valves
Overhaul 14 fuel oil and compensating water valves
Overhaul 7 main ballast tank blow valves
Overhaul 56 missile compensating valves
Overhaul 31 plumbing system valves
Overhaul 83 service air valves
Overhaul 254 missile air valves in place
Overhaul 38 control air valves
Overhaul 84 potable water valves in place

In addition to the subcontracting consciously initiated at the start of an overhaul, it is sometimes necessary to subcontract other components after the start of the overhaul if a particular trade becomes severely short of manpower due to delays on a previous ship or unexpected work package growth.

In addition to real economies which are often realized by subcontracting, the shipyard (and thus, the customer) reaps gains from this technique through improved schedule adherence. The latter effect is predominant in most cases, but in some---sandblasting is a good example---the use of subcontracting enables the shipyard to avoid the expense of maintaining large specialized shops to accommodate the relatively infrequent demand for those services.

3. Shifting Assets Between Shops

This technique is a useful one during the ripout phase of an overhaul when excess capacity exists in the machine shops until equipment to be worked upon in the shops is removed from the ship. In this instance, the Repair Officer approves the temporary transfer of a number of Shop 31 (inside machinists) to Shop 38 to assist in the ripout phase. This supplements the usually scarce Shop 38 resources and enables the similarly scarce Shop 31 personnel (who cannot begin work until equipment is in the shop) to begin their repair work sooner.

4. The Use of Borrowed Labor

In unusual circumstances, NAVSEA permits one Naval Shipyard to draw on the excess personnel resources of another.

Because this is quite expensive, however, it is normally used only as a last resort to maintain a schedule in severe jeopardy or, in instances where organized, specialized services exist at one shipyard and the cost of acquiring the same services at Mare Island would exceed the cost of using the former shipyard's assets. Use of this technique must be approved by the Shipyard Commander.

5. Changing the Schedule

Although listed under SCHEDULE ADHERENCE OPTIONS, use of this technique really represents an admission on the part of management that, for one reason or another, the existing schedule cannot be met. As discussed earlier, any readjustment of the schedule on one ship can have far-reaching effects on other ships as the orderly peaking and tapering off of trade manning is disturbed. It then becomes possible to have multiple ships approaching the same major key event simultaneously, a situation the shipyard labor force cannot adequately support.

To minimize these effects, the Repair Officer's practice is normally not to reschedule key events not on the critical path (figure 2), even if they are abused. Often, because of the "schedule early" philosophy employed (Chapter IV), minor key events can be missed without affecting the overall schedule. When it becomes apparent that a critical path key event will be missed, the Repair Officer communicates this fact through the Production Officer to the Shipyard Commander who makes the ultimate decision. If the

availability completion date is affected by the change, the customer's concurrence is requested by message. Otherwise, the change is made and reported to NAVSEA in the next monthly update of the key event schedule (Chapter IV).

E. THE SCHEDULE ADHERENCE CHALLENGE

The author has sought, in the preceding chapter, to develop for the reader the underpinnings necessary to understand the challenge of schedule adherence. If he has conveyed nothing else to the reader in these chapters, the author hopes that the dynamic nature of the schedule adherence problem is now apparent. There are no absolutes, no black and white situations, and few actions that can be taken which are without side effects somewhere else. As the Repair Officer stated, "Maintaining schedules is an art---not a science. Judgement, common sense, and experience are vital to the process."

VII. SUMMARY

A. PURPOSE

The author has endeavored in this research to document an exceedingly complex and elusive managerial process, both for the purpose of recording the features of this process for the benefit of future students of the subject and also to demonstrate the problems confronting shipyard managers in all shipyards. This chapter briefly reviews the important points presented.

B. SHIPYARD DESCRIPTION, ORGANIZATION, AND STRATEGIC PROFILE

Chapter II described the role of Mare Island Naval Shipyard in the Naval Shipyard Complex, described its physical location, and noted that the present work force fell short of projected work requirements and that the Production Shop skill level had declined in recent years. In this chapter as well, the shipyard production organization was discussed, including the immediate senior in the chain of command and the relationship with the customer. The computerized Long Range Planning System method of ship overhaul assignments was explained and the resulting planned ship load at Mare Island was shown and explained. The goal of the Mare Island production management process---work accomplishment, on schedule, and at minimum cost (for that schedule) was stated.

C. TYPICAL OVERHAUL SEQUENCE

Chapter III introduced the concept of key events and discussed the use of key events in defining the overhaul sequence. A typical nuclear submarine overhaul sequence was displayed and discussed.

D. DEVELOPMENT OF THE CONSTRAINTS

Chapter IV developed the basic parameters with which any production management scheme must constantly reckon---estimated (or target) cost, available work force, authorized work package, and approved schedule. The author pointed out that the authorized overhaul duration and scheduled dates are imposed upon naval shipyards by CNO after consideration of such factors as projected work to be done, refueling requirements, and strategic considerations. The author also explained that within the general bounds of this approved duration and time span the shipyard is able to sequence and schedule the overhaul milestones (key events) to suit. It was noted that the scheduling philosophy in practice at Mare Island at the time of this research was to schedule individual overhaul activities to occur at their earliest possible time to enable timely selection of alternative courses of action if delays were encountered in order to permit accomplishing the activity without delaying the overall projection completion date.

Continuing, Chapter IV showed how the authorized work package for a nuclear submarine overhaul was composed and constructed by activities external to the shipyard and how, given this work package, schedule, work force, and cost estimates could be developed. The Long Range manday projections made

by Mare Island based upon the projected and known work on assigned overhauls is the basis for personnel work force adjustments undertaken. Similarly, Short Range manday estimates developed by the shipyard as specific work requirements are clarified, after adjustment for growth and shop performance, constitute "will-cost" manday estimates which form the basis of the sales estimating procedure and detailed ship manning profiles. These estimates enable a projection to be made of workforce excesses or deficits (as is presently the case).

Finally, Chapter IV noted that Mare Island is a NIF activity whose accounting goal is to operate, in the long run, with neither profit nor loss. With this as background, two types of cost estimates were introduced---the final initial sales estimate (used at the pre-arrival conference to advise the customer of the projected cost of the authorized work so that authorized work adjustments may be made, if desired) and the fixed price estimate. The latter, developed at the 50 percent completion point in the overhaul, is the shipyard's offer to the customer for a fixed price on the overhaul completion at that point in time (the shipyard assumes the risk of overruns but reaps the gains of undercutting this estimate). Chapter IV further discussed the implications of either low or high fixed price offers on the ultimate desired "zero balance" in the shipyard's retained earning account. The author made the point that acceptance of the fixed price offer by the customer "seals" the work package against further

growth. Each new work item from that point onward is separately negotiated with the customer as to cost and schedule impact. The author also noted in Chapter IV that the emphasis in the NIF accounting system on neither profit nor loss serves to place a premium on performing in accordance with prior estimates rather than performing as well as possible. While it is not likely that any shipyard interprets the intent as such, this accounting system goal seems counter to good management practice and provides no clear incentive for aggressive cost controls.

E. MANAGEMENT TOOLS AND THEIR USAGE

In Chapter V, the author categorized the various aids available to assist the Repair Officer in the monitoring and control of the production process on several ships simultaneously into four broad groupings: Shipyard MIS products, Non-nuclear Composite Products, locally generated graphs, forms, and written reports, and verbal reports and feedback devices. An explanation of the Non-nuclear composite---a locally developed computerized work progressing system---was given and this system was compared with the standard Shipyard MIS. Examples and illustrations of the documents and inputs actually used in each of the four cited groupings were given and a visual summary, Figure 18, was presented at the end of Chapter V.

F. SEEKING SCHEDULE ADHERENCE---THE TRADEOFF PROBLEM

In Chapter VI the author brought together the material presented in previous chapters and explained, given the various constraints, the process and philosophy employed at Mare Island to seek schedule adherence. The author noted early in this discussion that cost was not a driving consideration for most production management decisions at Mare Island because of the philosophy practiced there that striving to achieve the schedule simultaneously achieves a near-optimum control over costs. The author also noted as implicit in this philosophy the assumption that production is efficient and without wasted motion or costs. The author next discussed the assignment of project and job priorities and the limitations imposed by (1) submarine and (2) multi-ship environments on orderly manning. The general techniques of bottleneck identification and resolution were also presented.

Finally, the author discussed in detail the various options available to the Repair Officer as he seeks to maintain schedules on several ships simultaneously: use of overtime, the use of subcontracting, inter-shop personnel transfers, use of borrowed labor, and changing the schedule. Significant among these are the use of overtime, which, although restricted by NAVSEA, provides efficiencies and cost savings in the long run. Similarly, subcontracting, properly applied, can yield economies. Further, both of these techniques, which are widely used at Mare Island, tend to offset the aforementioned labor shortage and bring true schedule adherence within grasp.

VIII. SUGGESTIONS FOR FURTHER RESEARCH

A. EFFECTIVENESS MEASUREMENT

> "The ultimate measure of our effectiveness is in the delivery of our ships on time at a competitive cost." [7].

In this statement, Mare Island proposes an intuitively appealing means of assessing effectiveness.

The author decided early in the research to refrain from any attempt to render value judgements on the process documented in the research in order to maintain an objective perspective in recording that process. Had such an evaluation been undertaken, however, using the above criterion, or any other which might at first glance seem appropriate, insurmountable difficulties would have been encountered. The problem in attempting to assess shipyard performance in quantifiable terms is the fact that every overhaul is different, and the ever-present variables of ship type, ship age, ship operating schedule, material availability, governing directives and work standards, labor force size and skill level, inflation trends, and general managerial priorities operate so as to really obfuscate comparisons. One might think, for instance, that schedule adherence is black and white--either the allowed date is met or it is not. In the case of a schedule extension due to a manpower shortage on one ship caused by emergent work on the preceding ship, how does one assess liability in such an instance? Similarly, attempts to

analyze shipyard final cost data as compared to fixed price (the difference being the net change in the shipyard's retained earnings account) can be exceedingly difficult. What does it mean, for instance, when on five ships in a row cost overruns are incurred? It could mean, obviously, that either schedule control or cost controls were poor (or both). It could also mean, however, that some factor was operating so as to render the price estimates consistently under the true figures. This, in turn, could be traced to any one of the component factors involved in a cost estimate---mandays, reserve factors, performance factors, material factors, etc.

The author was overwhelmed by the apparent difficulty of this problem and yet considers that some valid comparative measure would be of assistance not only to management of the shipyard in properly defining the problem area in questionable situations such as discussed above but also to NAVSEA and CNO in determining schedule durations and ship assignments.

Development of such a measure is suggested as a subject for further research.

B. NIF ACCOUNTING EMPHASIS

The author remains concerned that the NIF accounting system together with the (desired) fixed pricing arrangement seems to offer no clear incentive to control costs other than to meet the fixed price estimate.

Investigation of this facet of the NIF accounting system to determine whether such an incentive is feasible is suggested as a topic for further research.

C. SHIPYARD MANAGEMENT PRACTICES

The author, in completing this report, became impressed with the range of management aids and techniques used by the Repair Officer at Mare Island. Particularly innovative, it appeared to the author, were the use of manpower loading charts, the Non-nuclear Composite, and the Repair Officer's practice, in the area of ship manning, to provide shop heads general priority guidance and then to monitor the results of the implementation of that guidance by other means.

It occurred to the author, then, that other shipyards surely have similarly innovative techniques, perhaps in different areas. A compilation of such techniques would, it seems to the author, be an invaluable aid not only to students of the production management process, but also to those involved in its day-to-day operation.

Documentation of such techniques at other naval and private shipyards by techniques such as was employed in this research is suggested as a topic for further research.

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